EDUCATION 4.0 LIVING LABS

For the students of the future.

R.6.2. Set of identified disciplined

for the Project Education 4.0: Living Labs for the Students of the Future (LLSF)
Contract number 2021-1-RO01-KA220-HED-000032176

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Responsible:	University POLITEHNICA of Bucharest

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List of participants

Participant No *	Participant organisation name	Acronym	Country
1 (Coordinator)	University POLITEHNICA of Bucharest	UPB	RO
2	Universidade NOVA de Lisboa	NOVA	PT
3	Universita Politecnica delle Marche	UPM	IT
4	Universidad Nacional de Education a Distancia	UNED	ES
5	Tel Aviv University	TAU	IL

Revision history:

Rev	Date	Partner	Description	Name
1	13/Jul/2022	UPM	First draft	Susanna Spinsante
2	27/Jul/2022	UPM	Final draft	Susanna Spinsante

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1. INTRODUCTION

In this project, five universities are working together to create a training environment where students learn at their own pace through experimentation and the use of digital technologies, by actively working with data and applications over smart remote laboratories. These labs will support online training for smart specialization on IoT and Big Data technologies, innovation through common data procreation and seamless international collaboration in IoT and Data Engineering.

To reach the above-mentioned aims, the project consortium originally identified three digital laboratories to be developed: by the University Politehnica of Bucharest in Romania (UPB, P1), by the Universidade NOVA de Lisboa in Portugal (NOVA, P2), and by Università Politecnica delle Marche, Italy (UnivPM, P3). As a first step to start identifying what kind of contents could be delivered to students and also provided by partners to populate the digital learning and training environment, in the framework of the activity **A.6** "*Analysis of the set of existing disciplines in the participating entities and of the training needs*", Università Politecnica delle Marche prepared a short survey to which each partner was asked to participate, giving information about the identified discipline(s) that could be contributed to the training environment. Three partners (P1, P3 and P5) answered the survey and the answers provided are analyzed in report R.6.1. *Report of collected data through questionnaire*.

In this document, the focus is on the identified disciplines, with the aim of providing an overview of the available information that should be helpful to design an integrated and multidisciplinary learning environment.

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2. IDENTIFIED DISCIPLINES BY PARTNER UPB

UPB (P1) aims to set up within the digital learning environment a virtual infrastructure that will allow for remote teaching of ICT disciplines, from Big Data / Cloud concepts, to mobile computing and Internet of Things. The discipline identified by UPB is, in fact, **Cloud Computing**, that introduces students to notions related to Cloud Computing and prepares them for the correct understanding and use of the concepts, models and particular methods of developing Applications and Services that run in specific environments such as Cloud Computing. The course starts with the presentation of the basic notions specific to the field of Cloud Computing, such as Infrastructure as a Service (IaaS), Container as a Service (CaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) and teaches students more advanced elements of security or business economic models.

COURSE SYLLABUS
1. Program Information
1.1 Higher Education Institution: National University of Science and Technology POLITEHNICA Bucharest
1.2 Faculty: Faculty of Automatic Control and Computers
1.3 Department: Computer Science
1.4 Field of Study: Computer Science and Information Technology
1.5 University Program: Advanced Software Services
1.6 Study Cycle: Master’s Degree
1.7 Language of Instruction: Romanian
1.8 Geographic Location of Studies: Bucharest

2. Course Information
2.1 Course Title (RO): Cloud Computing
2.2 Course Instructor: Prof. Dr. Eng. Ciprian DOBRE
2.3 Seminar/Lab/Project Instructor: Assoc. Prof. Dr. Eng. Radu-Ioan CIOBANU
2.4 Year of Study: 1
2.5 Semester: I
2.6 Type of Evaluation: E (Exam)
2.7 Course Type: Mandatory
2.8 Course Classification: DA
2.9 Course Code: UPB.03.CTI.M.09.R.I.0b.3

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3. Total Hours (Teaching Activities per Semester)
3.1 Number of Hours per Week: 4
3.2 Course: 2
3.3 Seminar/Laboratory/Project: 2
3.4 Total Hours in the Curriculum Plan: 56
3.5 Course Hours: 28
3.6 Seminar/Laboratory/Project Hours: 28
Distribution of Time Allocation:
Self-study, course materials, bibliography, and notes: 40 hours
Additional research in the library and specialized electronic platforms: Included in self-study
Preparation for seminars/labs/projects, assignments, papers, portfolios, and essays: 40 hours
Tutoring: 8 hours
Examinations: 4 hours
Other activities (e.g., teamwork): 17 hours
3.7 Total Individual Study Hours: 69
3.8 Total Hours per Semester: 125
3.9 Number of Credits: 5

4. Prerequisites (if applicable)
4.1 Curriculum Prerequisites: Successful completion of the following courses:
Computer Programming
Communication Protocols
Parallel and Distributed Algorithms
4.2 Learning Outcome Prerequisites:
Understanding software application development principles
Familiarity with at least one software development technology

5. Requirements for Optimal Course Conduct (if applicable)
5.1 Course: The course is based on multimedia materials; therefore, a video projector is required.
5.2 Seminar/Laboratory/Project: Workstations with internet access are required in the laboratory.

6. General Objective
The course introduces students to Cloud Computing concepts and prepares them to understand and effectively use the specific concepts, models, and methods for developing applications and services running in Cloud Computing environments.
The course starts with fundamental concepts of Cloud Computing, such as Infrastructure as a Service (IaaS), Container as a Service (CaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). Students will become familiar with advanced elements such as security and business economic models.
By the end of the course, students will be able to understand and use the models and mechanisms that underpin Cloud Computing environments and platforms. Additionally, students will acquire the necessary skills to develop applications and services that run in Cloud Computing environments using Docker and Kubernetes.

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7. Learning Outcomes

Knowledge

- Describe and differentiate between Cloud Computing concepts such as IaaS, PaaS, CaaS, and SaaS.
- Define specific domain concepts (e.g., scalability, resilience, fault tolerance, virtualization, SLA, etc.).
- Understand security issues in Cloud environments, economic models for Cloud Computing, and Cloud Service models.
- Understand and describe mechanisms and tools specific to the development and execution of Cloud services and applications.
- Comprehend concepts for Business Grid, Cloud Computing Platforms, and Cloud Service Development Methodologies.
- Define container and containerization concepts using Docker and container orchestration and microservices through Kubernetes.

Skills

- Implement demonstrative applications based on the Cloud Computing paradigm.
- Justify identified solutions and explain problem-solving methods.
- Work and collaborate effectively in a team.
- Apply critical thinking principles in practical situations.
- Experimentally test the implemented applications.
- Identify solutions and design software architectures.
- Develop scientific papers and reports.
- Defend and justify identified solutions/methods.
- Responsibility and Autonomy
- Select and analyze suitable bibliographic sources.
- Respect academic ethics principles, properly citing bibliographic references.
- Collaborate effectively with colleagues and faculty during academic activities.
- Demonstrate autonomy in organizing learning situations or problem-solving tasks.
- Apply professional ethics and deontology principles when analyzing the technological impact of proposed solutions on the environment.
- Demonstrate real-life management skills such as time management, teamwork, and conflict resolution.

8. Teaching Methods

The teaching process will include lecture-based methods in the first part of the semester, during which the instructor will introduce students to the core concepts of Cloud Computing to establish a minimum knowledge base for all participants.

The second part of the semester will focus on involving students in research and documentation activities. Students will select relevant Cloud Computing articles, study them in teams, and present their findings during class sessions.

This approach will encourage:

- Independent learning skills
- Teamwork and collaboration
- Assertive communication and public debate

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During these presentations, students will be encouraged to engage in active dialogue with both the presenting team and the audience to foster critical thinking and constructive discussions.

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3. IDENTIFIED DISCIPLINES BY PARTNER NOVA

At the Universidade NOVA de Lisboa in Portugal the digital lab will focus on the integration of digital equipment into IoT applications and services, like tools for Smart Cities and eHealth.

Course Syllabus – Sistemas de Aquisição de Dados (SAD) / Data Acquisition Systems (DAQ)

Abstract

The course 'Sistemas de Aquisição de Dados (SAD)' introduces students to the principles, tools, and practical applications of data acquisition systems. Throughout the semester, students explore sensor technology, analog and digital signal conditioning, serial communication, A/D conversion, and system integration using platforms such as Arduino, PIC24, and LabVIEW. The course combines theoretical grounding with hands-on practical projects to prepare students for designing, configuring, and implementing complete DAQ systems in real-world contexts. Emphasis is placed on critical thinking, collaboration, and industry-aligned competency development, culminating in an understanding of Education 4.0 frameworks and the role of cyber-physical systems in modern engineering education.

Keywords: DAQ, Signal Conditioning, Sensors, Arduino, LabVIEW, Education 4.0, Cyber-Physical Systems

Jobs Requiring These Skills: Embedded Systems Engineer, Automation Engineer, Instrumentation Specialist, IoT Developer, Control Systems Engineer

Academic Target Group: Bachelor and Master-level Engineering Students

Target Group: Electronics Students, Computer Engineering Students, Automation and Control Students

Evaluation Method: Video presentation, Peer-reviewed report, Practical project submission, Live demo

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Equipment Used in Teaching: Arduino Uno, PIC24 Explorer Board, Sensors (LDR, Hall, etc.), Oscilloscope, PC with LabVIEW

Multimedia Used in Teaching: Lab simulation videos, YouTube tutorials, Live coding sessions, Presentation slides

Class Requirements: Basic electronics knowledge, Familiarity with programming (C/C++), Access to a computer with USB, Internet connection for remote labs

Course Modules

Module 1: General Introduction

Module 2: Evaluation Methodology

Module 3: Practical Work 1 – Acquisition System using PIC24

Module 4: Practical Work 2 – Arduino Sensor + App + Server Integration

Module 5: Theoretical Component – How to Present a Study

Module 6: DAQ Fundamentals

Module 7: RS-232 Serial Communication

Module 8: Introduction to Sensors

Module 9: Signal Conditioning – Basics

Module 10: Signal Conditioning – Filters and Converters

Module 11: Resistor Sizing and Debouncing

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4. IDENTIFIED DISCIPLINES BY PARTNER UNIVPM

At **UnivPM (P3)**, the digital lab will focus on audio applications and electronic measurements, with the possibility to get access to specific measurement instruments (such as a binaural mannequin, or a high-sampling rate digital acquisition system) and design different experiments to test the effects of surrounding environment on audio perception, and to measure several ambient and physiological parameters during experimental test campaigns involving subjects. Through the laboratories and connected dashboard, students, researchers and teachers from partner universities will be able to connect and extract data from the various sensors installed within the infrastructure.

The identified disciplines by UnivPM are "Sensors and Transducers" and "Multirate Digital Signal Processing and adaptive filter banks".

The following section provides information about the identified disciplines, extracted from the corresponding official syllabi published on the faculty website.

<u>Sensors and Transducers</u>

PREREQUISITES

Fundamentals of electronic measurements, instrumentation and electronics, basic knowledge of physics, circuit theory, and EM fields.

LEARNING OUTCOMES

Knowledge and Understanding.

The course introduces the student to the operation and characterization of the main types of sensors and transducers (operating principles, physical model, metrological characteristics, main construction technologies), providing methodological knowledge for a correct interfacing between these devices and the control and processing equipment that exploit their signals. This way the student understands how to design and implement simple acquisition and processing systems for the signals supplied by the transducers.

Capacity to apply Knowledge and Understanding.

The course provides the ability to identify the sensors and transducers suitable for the different physical quantities of interest, to design their respective signal conditioning and interface circuits, and to design and apply correct measurement methodologies.

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Transversal Skills.

During the course, the transversality of the knowledge that the students will be able to achieve will be highlighted, determined by the multiple and differentiated areas in which the course contents are applied, in the context of information engineering. The ability to perform practical activities to apply the acquired knowledge, about which students will be requested to report, will allow the students to develop their technical communication skills so that it turns out to be relevant, timely and effective.

PROGRAM

- Sensors
  Basic definitions. The measurement process. Basic applications of sensors: measurements and process control.
- Metrological characterization of sensors
  Model of a sensor. Characterization of a sensor. Parameters for the characterization of the static and dynamic behavior of a sensor. Operating conditions.
- Passive sensors
  Principle of operation. Resistive sensors. Capacitive sensors. Inductive sensors. Magnetic sensors: the Hall effect. Magnetoresistance.
- Active sensors
  Principle of operation. Peltier, Thomson, and Seebeck effects. Piezoelectric sensors. Pyroelectric sensors.
- Optical sensors
  Principle of operation. Photo Detectors. Fiber optic sensors.
- Sensors and transducers for mechanical quantities
- Encoder. Inductive proximity sensors. Strain gage. Linear voltage differential transformer. Acoustic and vibration sensors.
  Integration of sensors and electronic instrumentation
  Equivalent circuit of a transducer. Noise and amplification of electrical signals. Signal conditioning. Smart sensors. Data acquisition devices.

DEVELOPMENT OF THE EXAMINATION

Learning Evaluation Methods.

The level of student learning is assessed through the development of a project and an oral test. The project is related to the interfacing of one or more sensors to an embedded board / microcontroller, the sensor metrological characterization and the execution of measurements, using the notions acquired during the lessons. The oral exam includes the presentation and discussion of a final technical report related to the project, and two questions related to the topics presented during the lessons.

Learning Evaluation Criteria.

To successfully pass the exam, the student must demonstrate, through the tests described above, that he/she has understood the fundamental concepts of teaching and in particular that he/she has acquired the basic skills related to the metrological characterization of

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sensors, to the conditioning of signals generated by the sensors and their use in measurement systems. The oral test will be evaluated based on the following indicators: completeness, exposure, relevance. The test as a whole makes it possible to ascertain the capacity for knowledge and understanding, the ability to apply the skills acquired and present the results, and the ability to learn and develop solutions in independent judgment.

Learning Measurement Criteria.

A mark of thirty is given, with possible praise. The minimum mark for passing the exam is 18/30.

Final Mark Allocation Criteria.

The minimum grade, equal to eighteen, is assigned to the student who demonstrates that he has understood the requirements of the assigned project, implementing a solution and presenting preliminary results, as well as being able to answer at least one question related to the program.

The maximum score, equal to thirty, is assigned to the student who demonstrates full autonomy in carrying out the project, reporting significant experimental results, as well correctly and fully answers both questions asked. The praise can be given to students who reach the maximum grade of 30/30 and show methodological rigor, high presentation quality, and ability to correlate the different topics of the course.

RECOMMENDED READING

General texts for exam preparation

• Ian Sinclair, “Sensors and Transducers”, Ed. Newnes, 2001.
• Subhas Chandra Mukhopadhyay, Krishanthi P. Jayasundera, Octavian Adrian Postolache, “Modern Sensing Technologies”. Series: Smart Sensors, Measurement and Instrumentation 29, Publisher: Springer International Publishing, Year: 2019.
• Webster, “The measurement, instrumentation and sensors handbook”, CRC Press
• R. Northrop, “Introduction to Instrumentation and Measurements”, CRC Press, 2017.

Electronic teaching material available on the University Moodle platform

<u>Multirate Digital Signal Processing and adaptive filter banks</u>
PREREQUISITES

Circuit Theory, Digital filters, Adaptive filters.

LEARNING OUTCOMES
Knowledge and Understanding.

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To know and understand advanced Digital Signal Processing (DSP) techniques applied to audio processing. In particular, the students will acquire knowledge in the field of multirate digital signal processing and adaptive filter banks, allowing the development of a real-time application in the field of audio processing.

Capacity to apply Knowledge and Understanding.

The student will be able to design and develop real time applications in the field of audio processing exploiting advanced Digital Signal Processing (DSP) techniques applied to audio processing. Such skills will be acquired also through the participation in a practical classroom project relative to the real time development on a selected software/hardware platform.

Transversal Skills.

The participation of the student in the classroom project will be developed in workgroups and it will culminate in the development of a real time application for audio processing and in the writing of a final technical report. These activities will contribute to providing the student with better judgment skills, to strengthen the ability to synthesize and communicate the obtained results, and to develop autonomous learning and analysis proficiency.

PROGRAM

Theory lessons (58 h)

- Review of circuit theory concepts, Multirate system and filter banks.
- DFT filter banks, QMF filter banks, paraunitary filter banks, Cosine modulated filter banks, Wavelet.
- Review of adaptive filters. Adaptive filters banks and aliasing problems. Application of adaptive filters banks: Digital Audio devices, Audio equalization algorithms, 3d Audio algorithms for immersive scenarios, Multichannel audio reproduction system,
- Audio/video teleconferencing systems, Active noise cancellation algorithms.. Real time implementation of multirate adaptive filters banks.

Exercises (12h)

- Real time implementation of audio signal processing algorithms, real time filtering, filter banks, adaptive filter banks

Laboratory (2h)

- Visit to the semi-anechoic chamber and description of professional audio instrumentation.

DEVELOPMENT OF THE EXAMINATION

Learning Evaluation Methods.

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The learning evaluation methodology consists of the presentation and discussion of a final technical report relative to a project focused on the development of a real time DSP algorithm exploiting the technical background acquired during the lectures.

Learning Evaluation Criteria.

The student is required to show an adequate comprehension of the concepts discussed during the lectures and to be able to apply them in an autonomous way in the fulfillment of the classroom project. Moreover, it is required that the student is able to clearly explain and synthesize the development and the results of the project through the discussion of the final report.

Learning Measurement Criteria.

The evaluation is performed according to a 30-point scale, 18 being the minimum passing grade.

Final Mark Allocation Criteria.

To obtain the minimum passing grade, the student is required to show his/her ability in analyzing and correctly solving the proposed project by using the technical background acquired during the lectures. The maximum grade is obtained when the student demonstrates his/her ability to autonomously develop the classroom project, solving technical issues and showing the functional properties of the algorithms through suitable experimental tests. cum Laude is added to the maximum grade when the student shows a scientific attitude in the project development and an outstanding level in the project presentation.

RECOMMENDED READING

1) P.P. Vaidyanathan, "Multirate systems and filter banks" Prentice Hall Signal Processing Series, Alan V. Oppenheim Series Editor

2) R.R. Crochiere, L.R. Rabiner, "Multirate Digital Signal Processing", Prentice Hall Signal Processing Series, Alan V. Oppenheim Series Editor

3) Kong-Aik Lee, Woon-Seng Gan, and Sen M. Kuo. Subband Adaptive Filtering: Theory and Implementation. Wiley Publishing, 2009.

4) Lecture slides.

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5. IDENTIFIED DISCIPLINES BY PARTNER UNED

The identified disciplines by UNED are “Computational Infrastructures for Massive Data Processing”, “Cloud Computing and Network Service Management”, and “User Centered Design”.

The following section provides information about the identified disciplines, extracted from the corresponding official description published on the faculty website.

Computational Infrastructures for Massive Data Processing

PRESENTATION

Working with massive data requires the use of computer infrastructures specifically designed for them. These infrastructures differ from traditional infrastructures in several aspects. To begin with, it is necessary to combine the computing power of many computers, building what is known as a computer cluster. On the other hand, it is necessary to use programming paradigms that can take advantage of the computing power of the cluster but in a simple way for the developer in charge of implementing the programs for the analysis of massive data. Both aspects can be developed using cloud provider services. This subject shows some of the most important technologies that allow the deployment of infrastructures for the processing of massive data.

Within this Master it is important to acquire a solid vision of the most used tools in this context, since they are essential to move and process massive data, both structured and unstructured.

CONTEXTUALIZATION

The subject "Computational Infrastructures for Massive Data Processing" is a subject of 6 ECTS credits, compulsory, taught in the first semester of the Master's Degree in Engineering and Data Science. It belongs to the subject "Infrastructures and Systems for data management" to which the subjects "Management/storage of unstructured information" and "Data management security" also belong. In addition to these, it is also related to the following subjects also available in the same Master:

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Programming in data environment
Data visualization

Cloud Computing and Network Service Management

PRESENTATION AND CONTEXTUALIZATION

In recent years, a large number of different applications have emerged, which generate data in a massive way. This amount of data has created scalability and performance problems in traditional database systems, based on the SQL standard. To meet these new storage requirements, NoSQL databases have emerged, which aim to end this problem by providing a more versatile storage structure than SQL and resorting to non-standard database structures to obtain greater scalability, improving performance.

Within this Master it is important to acquire a solid vision of the most used tools in this context, since Big Data architectures are intended to move and process massive structured and unstructured data, quickly and with highly scalable tools.

This course provides an overview of some of the different solutions on the market, classifying them by their type of storage, and taking into account their use in real projects within the Big Data context. The objective is to understand the structure of these tools and techniques from the point of view of their use and potential usefulness, going into the details of their internal functioning and the specialized criteria for their selection.

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4. CONCLUSION

The disciplines presented in the previous sections and contributed by each project partner represent the basis upon which learning contents, materials, and approaches for the LLSF will be drafted to setup a shared learning content as project output.

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