# R.6.1. Report of collected data through questionnaire

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# Contents

# 1. INTRODUCTION

Based on the project proposal, the main target of the Living Lab is *to enable students through active research activities to realize the actual impact of their choices on a real-life establishment with real people living/working inside*.
During the project, three digital laboratories will be developed: in the Politehnica University of Bucharest in Romania (UPB - P1), Universidade NOVA de Lisboa in Portugal (P2) and Università Politecnica delle Marche, Italy (UnivPM - P3).

At UPB, a virtual infrastructure will allow for remote teaching of ICT disciplines, from Big Data/Cloud concepts to mobile computing and Internet of Things. The UPB Research Institute PRECIS is equipped with a smart building management unit which will be provided as a virtual infrastructure. All around the building there are various sensors that will be able to be read and worked with remotely. Students will be able to form competences over emulators of such a system, and with the right security clearances even interact with live environments. Scientists will be able to create their own experiments, for example to test their theories on energy influence in the building. This is an example of a digital ecosystem fostering a living lab culture at UPB.

At UnivPM, 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.

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 and several others. 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. This will support not only research activities but also practical learning applications. All results will be readily available to the open public.

In order to support the definition of the digital labs and the related contents that are expected to be delivered to students, a short questionnaire was developed by UnivPM (P1), with the aim to collect some basic information about the set of existing disciplines in the participating entities and of the training needs. The questionnaire was delivered to ALL the project partners, not only to the three ones identified in the project proposal as the target digital labs. The questionnaire was administered by using an online form, leaving room for additional comments, suggestions and inputs from the respondents.

Partners P1 (UPB), P3 (UnivPM), P5 (UNED) and P2 (NOVA) provided answers to the questionnaire.

The questionnaire and the collected answers are described and detailed in this report.

The project's overall objective is to develop an international network of interconnected smart labs for innovative programs and engineering opportunities in the field of Internet of Things and data science.

TAU's role is to establish an online hub that operates as an automatic catalogue. Teachers and students will be able to access information and data regarding the various laboratories for teaching and learning. Additionally, the parties will be able to exchange knowledge and enhance their collaboration.

## 2. THE QUESTIONNAIRE ABOUT DISCIPLINES

Seven questions were included in the questionnaire, and they are reported in the following list:

Q1) What are the existing disciplines in your participating entity which will be included in the project?

Q2) What is the background knowledge needed to students to effectively attend the course?

Q3) What is the learning outcome expected from your discipline?

Q4) What are the main training needs in the discipline that will be included into the project?

Q5) How could a remotely accessible lab help in providing support to your discipline?

Q6) What kind of activities for the students in your discipline could be supported or enabled by an online living lab/network of labs?

Q7) What other disciplines different from "yours" could integrate the knowledge and provide students with a better learning experience? - Note: this question aims to identify possible connections among the disciplines of the partners, to setup a "degree".

It is possible to give a graphical representation, as the one shown in Figure 1, about the main sections of the questionnaire, and the corresponding questions belonging to them:

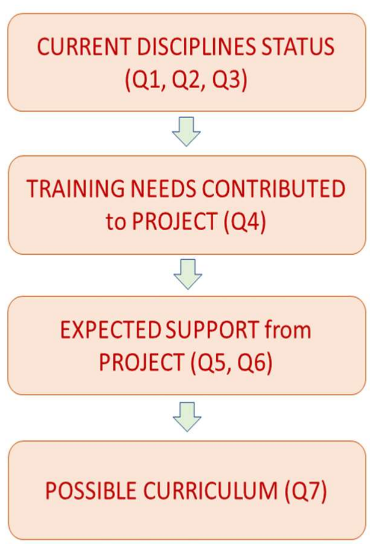


*Figure 1. Structure of the questionnaire.*

Questions Q1, Q2 and Q3 aim to collect a "picture" of the status of the disciplines identified by each participating entity, which should be transferred into a digital lab. Each partner was invited to provide details about the disciplines that were identified during the discussion of the project proposal, for contributing to the establishment of the digital labs. It's important to define the background knowledge requested to students in order to effectively attend the discipline and benefit from it. Similarly, the learning outcome expected from each discipline needs to be clearly identified, in such a way as to support the best digital tools that need to setup in order to support the students in their digital lab experience. Additionally, information about the expected learning outcomes helps to define an integrated curriculum possibly including disciplines from different labs.

Question Q4 is quite crucial: the identification of the training needs related to each discipline is fundamental for the definition of the set of digital tools needed to support the teaching and learning paths, and possibly to improve them with respect to a classical teaching approach. The question aims to collect information about the way each class is organized, in terms of time percent dedicated to frontal lecture, to laboratory experiences and numerical exercises. Of course, each discipline may have specific requirements, so it is important to get an overview of them, in order to properly arrange the digital learning environment. In some cases, the digital lab could enrich the learning experience, by providing additional opportunities (such as interactive training sessions, peer-to-peer review enabled by digital forum, self-administered questions in preparation for the exam, with automatic correction) which are not usually available to students in traditional learning environments.
In this sense, question Q4 is connected to the following question Q5, that focuses on possible ways in which a remotely accessible digital lab could support the learning process related to each discipline. Answers to this question should provide hints, ideas and suggestions for setting up effective digital labs supporting the learning targets of each discipline – even by using tools that have not been experienced before, in traditional classes.

Similarly, question Q6 asks to identify possible student activities or tasks within each discipline, which would benefit from the support of digital tools and functionalities enabled by the digital labs.

The last question, Q7, asks to identify possible complementary or supporting disciplines, with respect to the one addressed by the respondent, with the aim of getting useful ideas for setting up a possible integrated curriculum, in which different disciplines and digital labs from the different project partners could be harmonized to provide a kind of digital and connected study course.

The set of identified disciplines that are going to be contributed to the digital labs is described in detail in report R.6.2. In the following sections of this document, the information extracted from the collected answers to the questionnaire, from each responding partner will be presented and analyzed.

## 3. INITIAL MAPPING QUESTIONNAIRE ABOUT LABS

Prior to developing the automated catalogue, our goal was to understand the nature and primary purpose of each laboratory so that we could design the approach for the system. To map the participating laboratories, we looked for the following criteria:

- Existing technological infrastructure
- Available contents for teaching and learning
- Pedagogical models for teaching and learning
- Learning process and assessment
- Expected outcomes
- Potential collaboration with other labs

To conduct our research, we held five interviews with heads of labs participating in the project. As part of our preparation for this interview, our team provided them with the following questions in advance, the questions are found below:

**General questions about the labs:**

- Describe the lab?
- What is the main purpose of the lab?
- Briefly describe the standard operating procedures.

**Technical Infrastructure questions:**

- What technologies are being used in your lab? For example, sensors, networks, industrial apps, monitoring tools?
- What projects or research has been done in this lab already?
- Are there any articles that you have published while using this lab's infrastructure that you can send us to give us a better idea of how projects are conducted?
- What types of data are collected in the lab? and how? Manually? Computerized? Can you run simulations?

**Administrative questions**:

- Are the labs open 24/7? Or are there hours that professors or staff are present in which students use the lab?
- How do students use the lab today? (Physically, virtually, or both)?
- Can the students use the lab resources outside of the university? Are there remote options in place already? (For example, if students want to use the databases at home, could they?)

**Content questions:**

- What is the title of the course that you are adapting for this living lab project? Can you give us a brief description?
- Is there a syllabus for the course that you can give us?
- Are there class outlines, PowerPoints, or notes available for students that you can send us?
- What are the technical skills the students leave with after using this lab or participating in this course?
- Are there any other skills that students will acquire?

**Pedagogical questions**:

- How would you normally teach this course? (For example, do you lecture first then let students read about the topic then assess?)
- How was the class run in previous years?
- Are students instructed to read and study before class and then tested on materials when they show up to class?
- Do they work in groups for this assessment? Any prior knowledge needed before taking this class?

**Questions about students:**

- Are there opportunities in your course for student collaboration or is it mostly individual work? Can you give any examples?
- Are there opportunities in your classes for peer review? How is this typically done? Paper? Digitally like comments on a google doc?
- Do you think students will need a space to digitally collaborate with classmates? (Video chat, messenger, posts)
- What are important resources that students will need access to? (For example, databases, apps, file share apps etc.). Does your lab have access virtually?
- How do students communicate with professors in the past for the courses adapted for this project?

**Questions about student assessments:**

- How do you usually monitor student progress? (Posts on Moodle discussions, mandatory drafts?) Throughout the course are their small projects to check on students' progress? In which ways do you leave feedback (meetings in person/remote one on one meetings/ comments on a google doc/ voice notes)?
- How often do you leave feedback for students?

**Final wrap up questions:**

- Anything else you would like to add or expand on?
- Do you have any questions for us?

In addition to the interviews, we collected artifacts such as articles published by the labs, syllabuses of the courses that were being adapted, and any instructional PowerPoints that had been used in the past. These materials will eventually be uploaded to the automatic catalogue. The collected data from the interviews and artifacts were compiled and analyzed using qualitative method.

# 4. ANALYSIS OF ANSWERS ABOUT DISCIPLINES

## 4.1 ANSWERS to Q1

Each partner responding to Q1 gave details about the *existing* discipline(s) possibly contributed to the project.

According to partner **P1** (UPB), the discipline named **Cloud Computing** will be contributed. The course 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.

Partner **P2** (NOVA) will contribute the disciplines named **AIS - Architectures for Systems Integration**, and **Data Acquisition Systems**. The **Architectures and Integration Systems** course provides a comprehensive overview of key concepts and practices in the field of interoperability and integration. Students will explore the significance of interoperability in various industries, including Industry 4.0, Factories of the Future, and Digital Manufacturing. The course covers topics such as enterprise modeling, software architectures, and the integration and interoperability of business systems. Students will delve into the principles of model-driven development and model-driven interoperability, gaining insights into their applications and benefits. The course also showcases real-world projects, such as the Smart Health Project, which involves the sensorization of a medical device and the implementation of architectural solutions. Through hands-on exercises and practical work, students will learn about systems integration, the creation of libraries, and the integration of process management engines with physical systems. They will explore the challenges and opportunities presented by big data and systems integration, including the acquisition of data from wearables for the smartification of a kitchen. Additionally, the course highlights the importance of knowledge and ontologies in intelligent systems integration, providing a deeper understanding of how information is structured and utilized. Students will also explore the fascinating field of sensing enterprise and cyber-physical systems, gaining insights into their applications and potential. By the end of the course, students will have a solid foundation in architectures and integration systems, equipped with the knowledge and skills necessary to design and implement effective solutions in today's interconnected world. The **Data Acquisition Systems** course provides a comprehensive overview of the fundamental elements and principles involved in acquiring data from various sources. Students will gain a deep understanding of the components of a data acquisition system, including transducers and sensors, signal conditioners, and analog-to-digital and digital-to-analog converters. They will also learn about the hardware used for data acquisition, such as ADCs and data transfer to computers, as well as the role of computers and data acquisition software in the process. Throughout the course, students will have hands-on opportunities to work with microchips from the PIC24 family, including the PIC24FJ128GA010, conducting practical testing and implementing data acquisition solutions. By the end of the course, students will possess a strong foundation in data acquisition systems and practical experience utilizing microchips from the PIC24 family for various applications. The course further explores distributed data acquisition systems, highlighting their advantages and considerations. Students will be introduced to communication interfaces and protocols commonly used in data acquisition systems, including USB, IEEE FireWire, Ethernet, CAN bus, and more. Topics covered include serial and parallel communication methods, such as USB, IEEE-488 (GPIB), and others. The course also delves into commercial products available for data acquisition, both in terms of hardware (e.g., National Instruments, Keithley Instruments, Data Translation) and software (e.g., LabVIEW, MATLAB). Students will explore real-world applications and solutions offered by specific companies, with a focus on hardware and software integration. Additionally, the course touches upon the use of digital signal processing (DSP) and field-programmable gate arrays (FPGA) in data acquisition systems. It also explores data acquisition in specific areas, such as vehicles (e.g., CAN bus) and lifestyle/health monitoring (e.g., vital signs). By the end of the course, students will have a solid understanding of data acquisition systems, their components, communication interfaces, and practical applications across various domains. They will be equipped with the knowledge to design and implement effective data acquisition solutions for diverse scenarios.

Partner **P3** (UnivPM) identifies two disciplines that could be contributed to the project, namely **Sensors and Transducers**, and **Multirate Digital Signal Processing and adaptive filter banks**. The former addresses the main sensing techniques and the corresponding sensor technologies, with a focus on the transduction of different physical quantities into electrical ones (mainly, voltage and current) and the requirements of signal conditioning circuits. The latter aims 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.

Partner **P5** (**UNED**) similarly provided details about two disciplines possibly contributed to the project, namely **Computational Infrastructures for Massive Data Processing** and **Cloud Computing and Network Service Management**. The former discipline is focused on massive data analysis (sensor data, for example) and AI applications; the latter focuses on IoT technologies as a full module included in the subject and supporting these technologies with cloud technologies (IoT frameworks in several Cloud providers).

In an attempt to identify a possible organization of the proposed disciplines, based on keywords used in their description, the graphical representation of Figure 2 may be proposed:

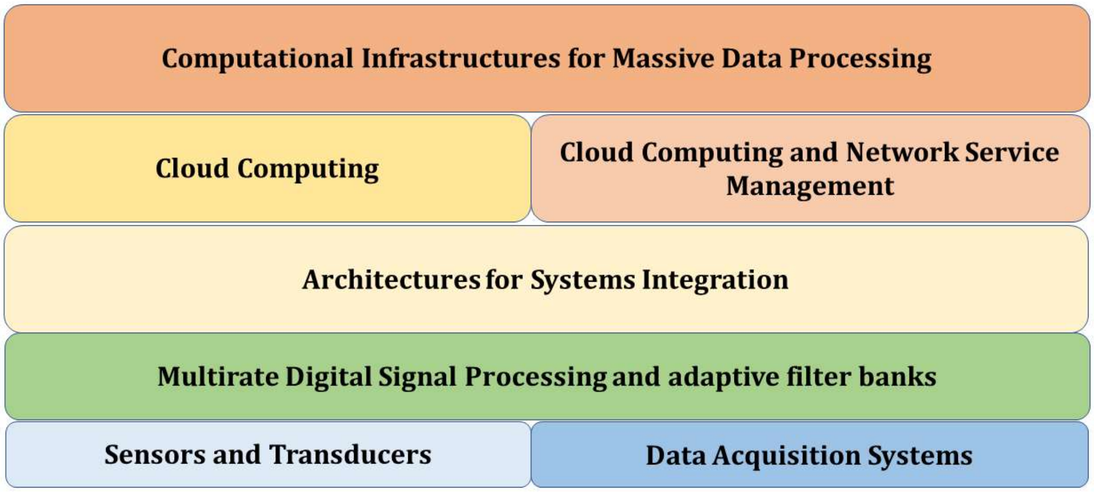


*Figure 2. Possible logical organization of the proposed disciplines.*

As shown in the Figure 2, at the lower levels of the proposed disciplines organization, i.e. “Sensors and Transducers”, “Data Acquisition Systems”, and “Multirate Digital Signal Processing and adaptive filter banks”, the mentioned disciplines deal with the low-level design of hardware and software components which are not directly accessible to “users”.

## 4.2 ANSWERS to Q2

Question Q2 requires to specify the background knowledge students attending each discipline should have, to perform effectively and benefit from the discipline itself.

About the discipline on **Cloud Computing**, the recommended background knowledge deals with programming, communication protocols, parallel and distributed algorithms. In a similar fashion, computing services, basic programming (several languages: python and node) and network protocols are suggested as pre-requisites for the **Cloud Computing and Network Service Management** discipline. On the other hand, background knowledge about computer infrastructures and networks, basic programming (python, scala), network security, statistics and distributed algorithms is recommended for the **Computational Infrastructures for Massive Data Processing** discipline. It appears that the disciplines identified by partners P1 and P5 have some common topics and items among the requested background knowledge, and this could facilitate the design of an integrated and harmonized digital lab.

To make the most of the **Architectures and Integration Systems** course, it is beneficial for students to have a foundational understanding of the following concepts: Basic knowledge of computer science and information systems: Familiarity with fundamental concepts in computer science, such as programming, data structures, and algorithms, as well as an understanding of information systems and their components. Understanding of software development principles: Prior knowledge of software development methodologies, principles, and practices, including aspects such as software architecture, design patterns, and software development life cycle. Familiarity with database concepts: A basic understanding of database management systems, including data modeling, database design, and querying using SQL. Knowledge of system integration concepts: An awareness of integration concepts, such as service-oriented architecture (SOA), application programming interfaces (APIs), and data exchange formats (e.g., XML, JSON). Awareness of enterprise systems: Some exposure to enterprise systems, including their components, functionalities, and their role within organizations. While not mandatory prerequisites, having a background in these areas will help students grasp the course material more effectively and apply the concepts in real-world scenarios.

For the two disciplines identified by partner P3, namely **Sensors and Transducers**, and **Multirate Digital Signal Processing and adaptive filter banks**, recommended background knowledge deals with physics, circuit theory, electromagnetic fields, statistics for the former one, and circuit theory and signal processing for the latter. With respect to the background knowledge suggested for the disciplines described in the previous paragraph, the two courses available at UnivPM are more related to signals and data than platforms or architectures, which motivates their graphical representation as "basic disciplines" (lower layers of the stack) in Figure 2.

## 4.3 ANSWERS to Q3

Question Q3 focuses on the learning outcomes expected from each discipline. The idea behind this question is to collect such information in order to analyze the resulting "profile" a student could gain from attending the set of identified disciplines in digital labs.

This information is also useful to identify possible missing skills and knowledge gaps that should be eventually addressed by future initiatives.

About the discipline on **Cloud Computing**, at the end of the course, students will be able to understand and use correctly the models and mechanisms underlying Cloud Computing environments and platforms. Students will also gain the skills needed for the proper development of Applications and Services running in Cloud Computing environments, through Docker and Kubernetes.

About the **Cloud Computing and Network Service Management** discipline, expected learning outcomes are:

- To know the basics of cloud systems
- To learn the basics of IoT networks, both at hardware and software level
- To acquire training on networked and distributed systems
- To distinguish between the three cloud service levels: IaaS (Infrastructure as a Service), PaaS (Platform as a Service) and SaaS (Software as a Service)
- To be able to develop IoT network solutions.

For the **Computational Infrastructures for Massive Data Processing** discipline, students attending the course should be able to:

- Distinguish between the main tools for injection, programming and storage of massive data, both batch and streaming
- Design programs for the analysis of massive data using the appropriate tools for the injection, analysis and storage of such data
- Describe the most important features of the main Big Data programming architectures and their forms of deployment both locally and in the cloud
- Identify and select the different configuration options in order to optimize Big Data infrastructures.

Again, these three disciplines appear to have some items in common, being generally focused on Cloud Computing, Networks, Platforms and Architectures. As such, it is reasonable to expect that these disciplines, once translated into digital labs, will benefit from the implementation of similar digital tools, to give students the possibility to earn and experiment effectively online.

Expected outcomes of the **Architectures and Integration Systems** course are: Comprehensive understanding of interoperability principles and practices in various industries, including Industry 4.0, Factories of the Future, and Digital Manufacturing. Proficiency in enterprise modelling and software architectures, enabling students to design effective integration solutions for business systems. Practical skills in systems integration, including the creation of libraries and the integration of process management engines with physical systems. Knowledge of model-driven development and model-driven interoperability, enabling students to leverage these approaches for efficient and scalable integration. Awareness of the challenges and opportunities presented by big data and systems integration, including the acquisition and utilization of data from wearables for intelligent applications.

Outcomes of the **Data Acquisition Systems** course: comprehensive understanding of data acquisition systems: Students will gain in-depth knowledge of the fundamental elements and principals involved in acquiring data from various sources. Proficiency in working with microchips from the PIC24 family: Through hands-on opportunities, students will develop practical skills in working with microchips such as the PIC24FJ128GA010, conducting testing and implementing data acquisition solutions. Familiarity with communication interfaces and protocols: Students will be introduced to commonly used communication interfaces and protocols in data acquisition systems, including USB, IEEE FireWire, Ethernet, and CAN bus. Knowledge of commercial products and software tools: Students will explore available hardware and software solutions for data acquisition, gaining insights into products from companies like National Instruments, Keithley Instruments, and Data Translation. They will also work with software tools such as LabVIEW and MATLAB. Understanding of specialized areas in data acquisition: The course covers data acquisition in specific domains, including vehicles (e.g., CAN bus) and lifestyle/health monitoring (e.g., vital signs), providing students with knowledge of specialized applications. By the end of the course, students will possess a strong foundation in data acquisition systems, including their components, communication interfaces, and practical applications. They will be equipped with the skills and knowledge to design and implement effective data acquisition solutions across various domains and scenarios.

About the two disciplines proposed by UnivPM, **Sensors and Transducers**, and **Multirate Digital Signal Processing and adaptive filter banks**, for the former, students attending this class should be able to:

- properly select and choose the right sensor for a specific measurement need
- identify sources of uncertainty in measurements and how to mitigate them
- analyze electrical and electronic requirements to interface each sensor to a measurement chain of systems/components.

About the latter, the expected learning outcomes deal with the capability to design and develop real time applications in the field of audio processing, exploiting advanced Digital Signal Processing (DSP) techniques applied to audio processing.

To ensure that the above learning outcomes can be met also by students engaged in online digital labs, specific tools and functions should be developed and integrated, probably different from those required or needed by the previous set of disciplines. In fact, the two disciplines proposed by UnivPM require some kind of physical interaction between a human operator (the student or a technician) and the system/sensor/transducer under study, which cannot always be mediated by a software component.

## 4.4 ANSWERS to Q4

Question Q4 addresses the main training needs related to the disciplines identified for possible inclusion into the digital labs.

As it is evident at this point, two groups of disciplines featuring similar aims/targets/needs are emerging: the former focused (in general) on cloud computing, and the latter focused (in general) on sensors, signals and algorithms.

About the group of disciplines related to the field of cloud computing, the following training needs have been highlighted:

- **Cloud Computing**:

  - frontal teaching in the classroom at least for 50% of the course total time, to provide the necessary theoretical foundations of cloud computing, microservices-based applications, Docker and Kubernetes;
  - lab sessions for the students, to get the chance to deploy their own cloud-based services with the help of teachers and assistants, for at least 35% of the course total time;
  - PC-based sessions to get acquainted with cloud computing software tools;
- **Cloud Computing and Network Service Management**
  - Distance teaching materials to provide theoretical foundations for Cloud technologies, IoT networks/protocols and solutions (40% of course total time);
  - Develop of cloud solutions and IoT platforms in the cloud on distance teaching mode at least for 60% of course total time (lab sessions are asynchronous works of the experimental activities for the development of these activities);
- **Computational Infrastructures for Massive Data Processing**
  - Distance teaching materials to provide theoretical foundations for Big Data technologies, Spark/Hadoop structures and Data Streaming Architectures (40% of course total time);
  - Development of analytical solutions using Spark/Hadoop (local/cloud) on distance teaching mode at least for 60% of course total time (lab sessions are asynchronous works of the experimental activities for the development of these activities).

It will be interesting to map the above listed training needs with the capabilities enabled by a connected, online living lab. Maybe, some of the referenced activities, such as virtual tutoring and evaluation of tasks among peers, could be possibly facilitated by the availability of a properly designed on-line platform, tailored to the discipline specific characteristics.

For the disciplines proposed by NOVA, the training need is to develop training materials to explore distance development of IoT related solutions to create smartification ideas or concepts to be deployed or tested in a kitchen furniture. This may include BPMN design of solutions to integrate different services to create smartified objects. For the second discipline, the need is to develop a way to remotely access for testing development and deploy of code in a PIC (microchip)

Regarding the two disciplines related to sensors, signals and algorithms, the following training needs have been reported:

- **Sensors & Transducers**
  - "frontal" teaching in the classroom at least for 50% of the course total time, to provide the necessary theoretical foundations of the physics behind sensors and transducers, and signal conditioning circuits;
  - lab sessions for the students, to get the chance to "put their hands" on real sensors, and how to physically interface sensors and electronic MCU boards/embedded boards to acquire measurement data, for at least 35% of the course total time;
  - PC-based sessions to get acquainted with software tools to analyze measurement data, compute measurement uncertainty and model the sensor behavior.

For the "frontal teaching", the availability of online tools such as questionnaires with scores, interactive forum for Q&A, online tests, could be very useful to allow students to test their level of understanding as long as the course develops, so that they can eventually identify and solve potential difficulties.

- **Multirate Digital Signal Processing and adaptive filter banks**
  - frontal teaching in the classroom at least for 80% of the course total time to provide the necessary theoretical foundations for digital signal processing,

discrete filtering, adaptive processing, real time elaborations, audio signal processing;

- lab sessions for the students to get familiar with real time audio systems and how to interface a sound card with the computer, loudspeakers and microphones;
- PC-based sessions to learn the basis of real time processing and the use of software tools chain for the creation of a real time application through the use of an audio acquisition system.

## 4.5 ANSWERS to Q5

Question Q5 asks the respondent to suggest how a remotely accessible lab could help in providing support to the discipline identified in the previous question. The answers to this question should be useful in guiding the implementation of the digital tools requested for the online accessible labs remotely available to students.

For the **Cloud Computing** discipline, students would be able to access remote resources (such as virtual machines or other virtualized resources) to deploy their own cloud-based applications. Furthermore, they would be able to create and configure various types of deployments such as grids, clusters, public/private/hybrid clouds.
Students could create solutions using IoT Frameworks (cloud) to consume/visualize data from the accessible labs, for the **Cloud Computing and Network Service Management** discipline. They would be able to consume and analyze data from IoT sensors, and could develop IA solutions (anomaly detector, data prediction, etc.) for the **Computational Infrastructures for Massive Data Processing**.

About **Architectures for Systems Integration**, the main objective is try to explore the integration of solutions in a collaborative way in such way that would mimc a real situation of having different engineers and designers work together for a common project.
Regarding and **Data Acquisition Systems**, having a remote access capability to a PIC24 microchip allows multiple individuals to simultaneously work on it without being dependent on direct physical access to a specific hardware. This enables greater flexibility

and collaboration, as users can conveniently connect to the PIC24 from different locations and perform their development tasks remotely.

About the **Sensors & Transducers** discipline, students could experiment with sensors accessible online and remotely installed, by collecting measured data and then analyzing them "locally" (e.g. data are downloaded following a given duration of the experiment and locally processed/analyzed by students). Students could have the chance to remotely control and configure sensors, for example by changing the sampling frequency or the full scale range or any other available configuration, based on specific experimental conditions of interest; remotely accessible instrumentation could be used by students to learn how to setup the instrument in order to perform a predefined set of measurements (so that each student can practice how to interact with the instrument frontend). For the **Multirate Digital Signal Processing and adaptive filter banks** discipline, students could experiment with professional sound acquisition system, to test real time applications (e.g., multichannel audio system with multiple loudspeakers and multiple microphones for acoustic echo cancellation, immersive audio system, room characterization, active noise cancellation) and also to test professional equipment such as binaural mannequin used for the characterization of Head Related Transfer Functions in Immersive audio rendering or to study the human sound perception.

From the collected answers, it emerges how the group of disciplines focused on cloud computing may maximize the exploitation of online digital labs, by giving students the access to real platforms and architectures for manipulating data flows and developing computational intelligence-tools. For the disciplines focused on sensors, signals and algorithms, the common expectation is to have the chance to enable remote access to physical lab equipment and instruments, or sensors, which will anyway need the “local” presence of an operator to interact with the hardware settings and configurations (e.g. setting up cable connections, switching on/off an instrument, change the position of a switch or physical control).

## 4.6 ANSWERS to Q6

Question Q6 further extends previous question Q5, by asking what kind of activities for the students in each discipline could be supported or enabled by an online living lab/network of labs.

For the **Cloud Computing** discipline, having resources from various locations might help students to get familiar with a more realistic cloud, where resources are heterogeneous, can be located in various geographical areas, and need to be configured for a seamless functionality. Moreover, they could use this geographical distribution to learn about data replication, sharing, etc. In a similar fashion, for the **Cloud Computing and Network Service Management** discipline, it would facilitate the integration of real-time consumption activities of sensor data with the IoT platforms studied in the course, as well as protocols (MQTT, etc.), and for the **Computational Infrastructures for Massive Data Processing** discipline, access to the laboratories would make it possible to have realistic data and even connect the generated data with Streaming systems and analyze/manage the information from the sensors in an smart way.

For the **AIS** discipline, the practical project that they have to do to test their skills got from the discipline, and for **DAS**, with this more students with more time may have access to a specific hardware.

About the **Sensors & Transducers** discipline, accessing a network of remotely connected living labs could give students the possibility to learn how to use different instruments, especially those that are not available in each participant's "local" lab; to design and setup experiments by exploiting the instrumentation/sensors/devices available in remote sites, and so how a network of distributed systems may work for the same measurement scope; to learn what are the requirements for connecting instruments and making them safely accessible from remote locations; to design and setup distributed sensing systems by exploiting the diversity of sensors/devices/systems available at each participant's lab. For the **Multirate Digital Signal Processing and adaptive filter banks** discipline, the remote access to the laboratory could allow the students to perform experiments with real setup that are not achievable in common environment, like the use of binaural mannequin in a semi-anechoic chamber ore the use of a multichannel input/output audio system.

## 4.7 ANSWERS to Q7

The last question Q7 aims to identify possible connections among the disciplines of the partners, to setup an "online degree", by integrating and harmonizing the different aspects of each discipline.

For the disciplines in the **cloud computing** group, students could benefit from the possibility of complementing the Cloud Computing knowledge with Big Data topics, or even with Mobile Computing courses that could help them implement clients for their cloud-based services. Other subjects belonging to different degrees, such as the Master's Degree in Computer Engineering [1][1], Engineering and Data Science [2][2], Research in Artificial Intelligence [3][3] and the Doctorate in Intelligent Systems [4][4], could benefit of the use of living labs.
The availability of sensor data would allow the use of different technologies to manage this information: web applications, AI, protocols and communications, ect. IoT is a very cross-cutting concept and is applicable in many areas of technology.

According to NOVA, for the **AIS** discipline, all from UNED, UnivPM, UPB; for the **DAS** discipline, perhaps the Cloud computing based disciplines associated to UPB and UNED plus the one related with sensors of UnivPM.

[1] http://portal.uned.es/portal/page?_pageid=93,71542259&_dad=portal&_schema=PORTAL&idTitulacion=310601&idContenido=8

[2] http://portal.uned.es/portal/page?_pageid=93,71396234&_dad=portal&_schema=PORTAL&idTitulacion=311001&idContenido=8

[3] http://portal.uned.es/portal/page?_pageid=93,71542259&_dad=portal&_schema=PORTAL&idTitulacion=310801&idContenido=8

[4] http://portal.uned.es/portal/page?_pageid=93,71412284&_dad=portal&_schema=PORTAL&idtitulacion=9613

According to the disciplines in the group focused on sensors, signals and algorithms, students could benefit from the possibility to complement the topics addressed in the **Sensors and Transducers** course with skills and competencies in the field of programming embedded boards, setting up web-based platforms for the collection and analysis of measurement data from sensors, use of machine learning tools for gathering knowledge from measurements in a data-driven approach. For the **Multirate Digital Signal Processing and adaptive filter banks** discipline, students could benefit from the possibility to complement the topics addressed in this course with skills and competencies in the field of C/C++ programming, setting up web-based platforms for the collection and analysis of data.

## 5. CONCLUSION

Based on the information collected through the questionnaire presented in the previous sections, partners in the LLSF project will design a training programme to setup a comprehensive and logically structured learning path, which should benefit from the availability of online tools, instead of resorting to them as an emergency-backup, as it unfortunately happened during the last Covid-19 pandemic times.