SUFFER: A Cloud System for Teaching Labs in Distance Education

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***Abstract*—During a pandemic, redesigning the education system to improve access to the available platforms at the universities originally designed for research and local use is necessary. The emergence of cloud computing services has solved many of the performance problems. This paper presents the characteristics of a cloud e-learning tool. In order to do so, the concept of cloud computing is analyzed, and the architecture of the cloud computing platform used in different courses of the Computing Engineering degree are described. This platform was used in a proof of concept in the 2019-2020 academic year. The evaluation results, both from teachers and students that have used it, show positive and promising results.**

***Index Terms*—Remote labs, online teaching, cloud computing application**

I. Introduction

For years, cloud computing mechanisms have been a key element in the digital age. Different solutions to online learning have been incorporated to the educational context. The goal has always been to improve the academic experience and to allow it to take place properly in spite of the physical and temporal restrictions [1]. An online learning platform in the cloud must be able to dynamically scale on demand, to offer the applications needed by the students, to be easily personalized to fit the particular needs of each student and to be easy to maintain. With this criteria, its incorporation into the academic institutions would be easier.

The current online learning platforms carry a high initial cost in infrastructure and existing software applications or in ad-hoc developments. The academic institutions are under financial restrictions, and as a result there is a shortage in human resources to operate, update and effectively administrate the existing infrastructure. Faced with this situation, the adoption of cloud computing can help the institution to reduce costs in infrastructure, software and human resources. This way, a school can rent these services only when they are needed, or at least tailor them to the current needs.

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However, for the most part of these tools are only used as a support for regular classes, or as a way to maintain that same regular method in the cloud. For example: AVIP, Google Meet and Microsoft Teams to teach; Moodle to access the contents and test the students; tutoring sessions through different forums or video call tools, etc. Meanwhile, cooperation tools are very limited, specially because, even though students have multiple platforms they can use, these are all hard to evaluate, and sometimes not even accessible to the teacher [2]. Not to comment that in these cases it is not easy to find tools that facilitate the correct feedback in academic contexts [3]. Having this type of tools is key in any environment, but it is even more so in the actual pandemic situation [4]. Even if the methodology is the main element needed to handle the current situation, providing access to tools that allow cooperation between students that are flexible and scalable is absolutely necessary [5], [6].

This report is presenting one of these tools named SUFFER, that follows a computation model in the cloud to offer different content to satisfy the current demands in teaching and research, working even in complex or demanding environments, like labs. The remainder of this paper is structured as follows: first the different possibilities for online teaching and which ones SUFFER offers will be commented; next an experiment carried out as a concept test will be presented and commented; lastly a series of conclusions will be provided.

II. Practical labs for cloud teaching

In recent years, teaching and learning platforms have become a natural tool for educational institutions. They support both on site and on line teaching. There is a huge amount of platforms offering long-life teaching, employees training, academic courses, etc. Some of the most popular platforms are Moodle, Blackboard, Sakai, etc. They provide a collaboration space for teachers and learners as well as a way for them to contact [7]. Prior to the identification of the elements that a virtual cloud teaching platform should have,

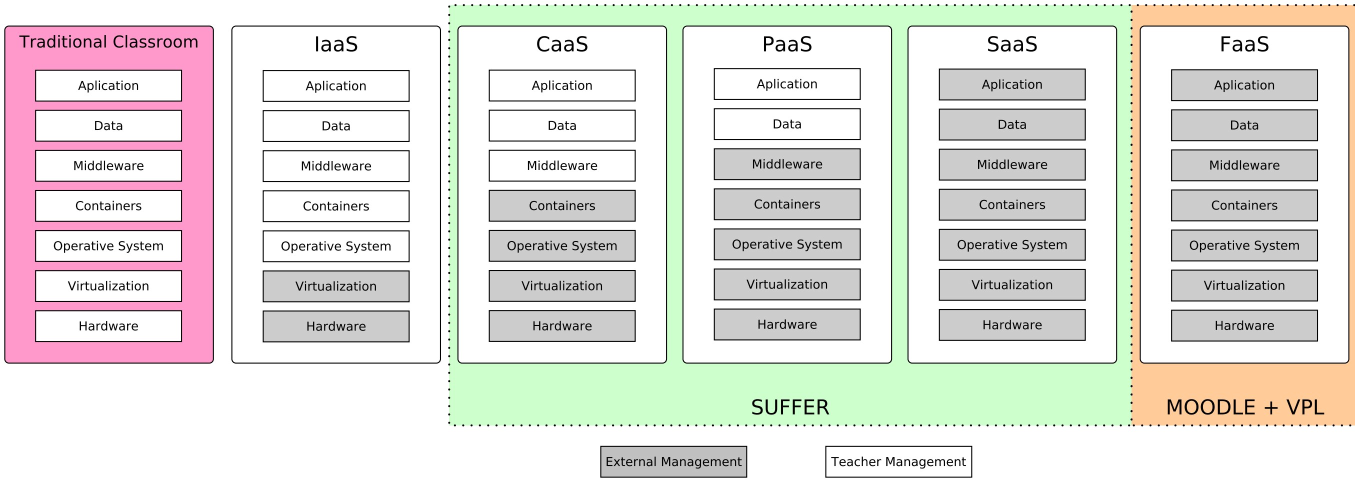

Fig. 1. Platform for cloud teaching. Teacher levels of participation

it is necessary to identify the tasks that students and teachers perform in classical teaching. On the one hand, the student has to take notes, make exams, send comments, perform individual and group assignments, access contents, etc. On the other hand, the teacher needs to manage the contents to be offered, tools to prepare tasks and exams, and communication and evaluation systems. These tools should offer students and teachers a way to perform education tasks following several models, such as, master class, seminars, practical sessions, tutoring, exams, reviews, etc. One of the most difficult parts, regarding virtualization, are practical labs because of their practical and tangible nature. This section shows a summary of which are the implications of this kind of labs and how they are moved to the cloud.

A. Traditional lab

Our staring point is practical teaching in a traditional classroom or lab. This teaching takes place in an institutional environment where students, teachers and physical tools such as PCs, pipettes, or plastic material, share the same place. Somehow, teachers and learners interact face to face in order to fulfil that knowledge transmission that takes place through direct experimenting of all the actors involved.

Although the lab is the key tool for the practical part of many courses, it presents several issues as Rosado shows in his work [8]: a) Normally, the equipment used is especially expensive, making it difficult to perform and repeat the experiments outside the lab; b) Many labs are overcrowded or underequipped due to budget constraints; c) Lab classes usually require a direct supervision and feedback from the teacher and an individual set of material for every student, which result in overcrowded environments, as already mentioned; d) Not always are the students ready to work with specific devices and techniques, risking expensive equipment. Besides all these issues, there is a new scenario, due to the pandemic situation, that can prevent onsite teaching to take place. In this case, students do not have access to the lab equipment, teachers can not use the lab tools and the lab is being used by no one. In some situations, a plausible alternative to solve all these issues together could be using the cloud for teaching.

B. Cloud lab

According to the proposals gathered from literature and the bidirectional needs expressed by teachers and learners, it is necessary to establish the set of services to be offered by a cloud system and how to link them to the traditional teaching/learning processes. In this context, once the elements of a usual cloud service structure have been identified [9], their application in learning environments will be evaluated. The more common cloud scenarios are presented in Fig 1. Their description is as follows:

1) Infrastructure as a service (IAAS): this model offers the user the elements needed to perform system tasks (processing, storage, networks, GPU, etc) in order to deploy and run arbitrary software. When transferred to the educational context, the teacher does no longer manage the infrastructure, as in the real lab, does not have physical access to the computer, but does have absolute control of the logical configuration of the system: operating system and applications.
2) Container as a service (CaaS): this mechanism relies on the concept of virtualization through containers. This concept is based on deploying ”preconfigured” systems avoiding the need of installing the corresponding software infrastructure. When applied to the educational context. This approach implies deploying basic prefabricated solutions offered by manufacturers and adapting them to the classroom needs.
3) Platform as a service (PaaS): this model does not allow the user to manage or control the underlying cloud infrastructure but it offers complete control over the applications deployed and their associated data. For the

teacher, this means that the working environment can include different data sources, or even can install new plugins and software initially not available.

4) Software as a service (SaaS): this model is based on the opportunity to offer the consumer the use of an application. The idea is to offer a multi-platform application to be used through another application of through the web browser. In this case, the teacher uses a preconfigured tool that offers a variety of elements to perform and visualize the work being done, such as Google Docs or Moodle, but with the limitation of not being able to install new extra applications.
5) Functionality as a service (FaaS): this mechanisme is more enclosed than all the previous ones, as the possibilities are limited to specific functionalities. An example of this kind of service can be observed in the Virtual Programming Laboratory of the Moodle platform, that is used when required. One of the main characteristics of FaaS is its resemblance to the serverless solutions, that is, they are only active when they are needed, but not always.

These scenarios have already been tested in different proposals for the educational context. For instance, Rosado [8] had already presented a work for teaching Physics in the cloud in 2005, and Orozco [10] did it for Chemistry. Java applets were used in the first work to simulate a lab environment although the grading system or teacher support are unclear. In the second work, a self-assessment system is proposed including true/false and autocomplete questions starting from a sequence of documents available on line. In the field of computer science, works related to tools such as VPL (Virtual Programming Lab) can be found [11]. VPL is a software tool that allows managing programming assignments inside Moodle. However, this solution is limited to one specific functionality, which is testing code, excluding part of the infrastructure available in a lab, such as robots.

III. Architecture

Taking into account the conditions described above, This work proposes SUFFER as a tool to move labs to the cloud. SUFFER lays out the possibility of deploying labs with different characteristics based on CaaS, PaaS and SaaS attending teachers' needs (see Fig 1). SUFFER can offer a complete infrastructure simulating a real PC (infrastructure as a service). It would allow offering practical labs for courses such as Operating Systems or Embedded Systems. But due to the huge amount of possibilities that this approach can offer, it is necessary to narrow down and monitor many more elements in the machine, both regarding maintenance and cibersecurity. For this reason, the more general perspective of the project has been postponed for future iterations. Figure 2 shows graphically the elements included in SUFFER in the context of robotic labs.

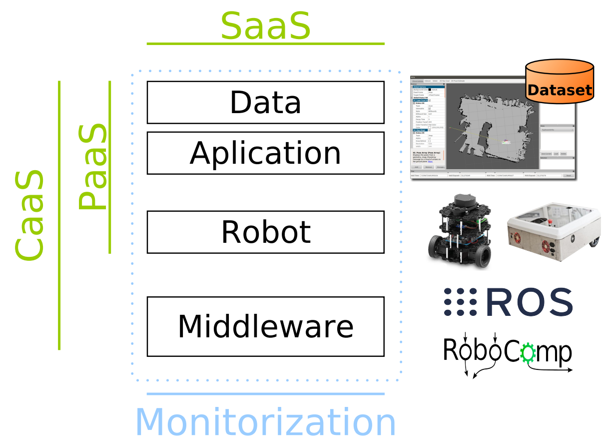

Fig. 2. Suffer Framework

A. Generator of Platforms

The main objective of SUFFER is to adopt an approach oriented towards services on cloud to provide the technological resources needed by the teacher and, thereby, by the student too. This way, the teacher can focus completely on the specific knowledge to be transmitted and the student can focus on getting it.

For the teacher that wants himself to deploy the software needed for his class, a pool of containers will be offered with just an operating system installed. In these containers, the teacher will have access to installing and removing everything needed. This way, not only the code of applications should be loaded, but also all technical requirements for coding, compiling and managing the applications to be used. The approach used to solve this scenario is mainly based on containers, and it is therefor associated to a CaaS scenario.

For the teacher that decides to use an approach based on predefined containers for his classes, an advanced environment will be provided with software already installed. This option prevents the teacher from the management of the middleware and minimizes configuration problems. This way, the teacher relies on the technologies supplied by the provider, and deploys the applications and the corresponding data sets together with the platform. This case is considered as PaaS solution.

The third option considered in SUFFER framework is the SaaS solution. In this case, the whole infrastructure needed for the lab is offered to the teacher, that is, students will be working with a closed platform where the addition of new content should be minimal. Although modifying the platform by adding new material can be blocked, we consider that offering the possibility to include new elements that could improve the class is the right choice for a successful practical session.

B. Monitoring System

Beyond the technological infrastructure of the lab, it is necessary to offer monitoring tools in order to reduce the inactivity time of the three main actors, that is, the tool, the teacher and the student. The tool should minimize the no productivity periods of time or the possible system crashes. The amount of money employed in hiring an infrastructure on the cloud can not be lost because of unavailability of the service. The goal is to provide distributed resources capable of being used in an optimal use.

Teachers should also have monitoring tools for the progress and evaluation of their classes so that a positive or negative evaluation of students' performance can be offered at the end of each session. For instance, figure 3 shows the state of four different sessions of students: two of them have not entered yet, and the other two are already working on their assignment. When used together with a videoconference tool, SUFFER allows the teacher to interact directly with the student desktop in order to solve or fix a problem.

Last, it is necessary to know the state and the use that the student is doing of the platform. This is not only important because of reasons related to providing feedback to the teacher, but also to guarantee that the user is not performing any illicit action by means of the platform. For this reason, SUFFER carries out a soft monitoring of the system with the network monitoring tool CICFlowMeter [12]. In addition, it records a set of data logs with timestamp that provide information about when and in which conditions the interaction with the system takes place during the practice session. This information will allow the teacher to predict the behaviour of the student during the class.

Fig. 3. Example of the teacher's window to supervise the students

These three lines of supervision allow the improvement of the resources of the cloud system and the services offered to every teacher. At the same time, they easy the optimization of the mechanisms used to properly provision the resources offered at any time. This supervision allows also the observation of possible limitations of the system and the proposal of mechanisms to solve them.

In the current state of the research, besides the direct supervision of the students by the teacher, SUFFER offers a monitoring system and also a mechanism to launch events associated to files and applications. Their source are mainly the log files provided by the applications and the user interaction with the terminal. This information turns out to be of great importance for lab activities related to computer science in particular. This monitoring can take place one time or through historic data. In both cases, the analysis of this data is of great value to analyze how students solve their practical assignments.

IV. Testing SUFFER

In order to validate the framework developed, an experiment has taken place as a proof of concept. The two goals of this test are:

1) Using SUFFER as a robotic virtual environment as a replacement of the traditional robotic lab.
2) Quantitative analysis of the performance of both teachers and students.

Teachers and students do not need to know about the functioning rules of the platform. The requirements for them are: 1) it is necessary for them to have a web browser; 2) it is desirable for them to have at least some basic knowledge about ubuntu or any other similar system; 3) the teacher can choose the way to access the platform from the information received by an email sent by the system. The next step is for the teacher to guide the session. When it is finished, he notifies us and we gather the information about the class and delete the machines.

A. Structure of the experiment

Using SUFFER is proposed to different postgraduate courses at University and, therefore, to the master and doctorate students enrolled in those courses.

The courses involved in the experiment were: Virtual Reality from the Master of Science in Computer Science (4 students); Robotics applied to aging biosanitary sciences from the Master of Science of Healthy Aging and Quality of Life (Inter-university studies) (15 students), both in University of León. In addition, SUFFER was also used in a training course in which a practical lab about reinforcement learning in robotics was included. This course was devoted to teachers of different areas and departments of the university.

From this point, every teacher manages the set of machines freely and notifies any issue than may prevent the practical session to take place.

B. Methodology

In order to give a practical lesson, we assume that the teacher knows the subject to be taught. This way, the sequence to follow with the teacher is always the same one:

1) The information about the machines requested for the class is received.
2) In some cases also the list of tools needed is provided.
3) The class takes place.
4) Information about the behaviour of the students in class is offered to the teacher.
5) The performance of the machines used for the class is evaluated from the technological point of view.

C. Results

The results have been obtained from the three experiments where SUFFER was used. In each experiment, the platform was used in sessions that took from one to three hours. The data obtained from these sessions were used for the platform evaluation. Table I shows the results collected from the questionnaires uses. This information is also available from the following link https://forms.gle/yKXF2u3U1J75Le7z7.

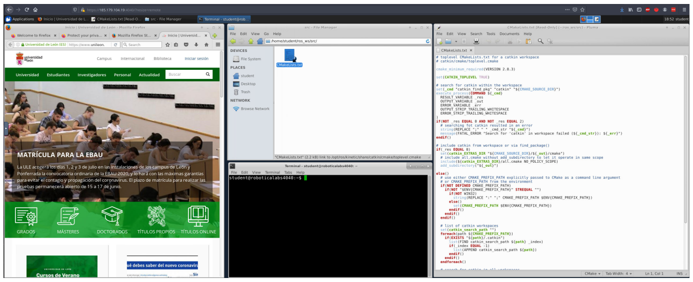

Fig. 4. Example of one of the desktop of a student using the platform.

V. Discussion

A. Traditional lab vs Cloud lab

The main goal of this work is to determine whether virtual laboratories can be used in environments with special computational restrictions such as robotics field. In order to achieve this goal, the approach proposed in [13] will be followed. According to the authors, the use of these laboratories allows to guarantee that the students acquire the required competences. Sometimes, this process implies the use of tools that are not always available or that have a temporary availability.

This issue about availability has been a sound one specially in the first sessions. For all teachers, students and researchers show a very positive opinion in general about having a cloud robotics lab already available with all the tools needed to start working pre-configured. Regarding advantages and disadvantages found by the different actors involved in the experiment of using SUFFER some issues have to be pointed out. The first one are the doubts about the resources needed for a practical class to take place. The issue about limited resources requires farther research. For instance, a ROS (*Robot Operating System*) using the Gazebo simulator requires something like 4 processors working at 100% of an Intel(R) Xeon(R) CPU E5-2640 v4 @ 2.40GHz machine when the student is fulfilling some of the exercises, although the RAM consumption is kept under 2GB. Authors are now working on stress tests of the system in order to assess the maximum number of students for a given provision of resources in the cloud.

Beyond these opinions, and regarding other aspects evaluated of the framework performance, three specific factors have to be brought to your attention: 1) Most of the persons participating in the experiment had previous experience with cloud applications (60%), and this fact could somehow bias the results obtained but at the same time shows the kind of actual student, teacher and researcher who use cloud tools on a daily basis both for education and also professionally; 2) The possibility offered to the teacher of remotely controlling students' desktop has been found useful by 100% of the participants; 3) The time needed to get used to the system has been generally a very short one.

Nonetheless, after this first experiment, it would be appropriate to carry out a standardized usability test or a technology acceptance one. In both cases, it would be interesting to study the differences between the different roles and their specific interests.

TABLE I
Results of the questionnaire showing advantages and disadvantages, Previous experience working with cloud applications (Exp.: Yes-1, No-0). Teacher's control (TC: Yes-1, No-0). Time to get used to it (TgU where Likert: 1-5). Recommendation of the system to be used in class (R:May-be-2, Yes-1, No-0).

	Advantages	Disadvantages	Exp	TC	TgU	R
A1	The interface. It is just like your own Linux PC. No effort needed to learn how to use a new interface.	None observed.	1	1	1	1
A2	Having all the software installed already available.	None observed.	1	1	1	1
A3	Very easy to use technology. All the contents for the course are already installed and configured, which eases the class progress. It all worked fast and stable.	None observed.	0	1	1	1
I1	A whole environment in the cloud ready to be used	Someone has to give you access to the platform	0	1	1	2
I2	You do not have to worry about installing the software you need to make your practical assignments.	None by now.	0	1	1	1
I3	It allows me to share my desktop with my teacher and other students.	You can not install any new tool.	1	1	1	1
I4	"Abstraction of the operating system. Be sure that all the students do have exactly the same versions of libraries and tools."	The possible limitation of resources.	1	1	1	2
P1	Normalization of the student's environment. Accessing through a web browser helps the teacher to solve problems of each student individually. Very intuitive tool to learn.	The access in the web browser seems not to be safe. Having access to the GPU may help for workshops of machine learning.	1	1	1	1
P2	Flexibility, monitoring, possibility of view the student's desktop and provide feedback to each of them.	It does not include a videoconference tool and an external one has to be used.	1	1	2	1
P3	Students do not have to install anything and teachers can watch the machine of every student	Sometimes, for some student whose connection is not very good, the system shows a slow performance.	0	1	1	1

B. Cibersecurity and Privacy

In this section, several points suggested by the work of Alshwaier et al. [14] have been considered. During the experiments, students have shown some reservations when using tools not supported by multinational technology enterprises because, to their understanding, they would guarantee their privacy. That is why some students prefer to spend several hours configuring their personal machines in order to fulfil their practical assignments. To our knowledge, this is more a perception than a fact. The tool implemented in University of León stored all the data in servers located in Spain, guaranteeing the European GDPR (General Data Protection Regulation). Even more, we are working on providing mechanisms to guarantee other extra aspects related to data security.

VI. Conclusions

This work presents a proposal to move the virtual classes in technological laboratories to a cloud system and, as a result, the SUFFER framework has been defined. Although the idea of the framework was initially considered for robotics laboratories, it can be applied to any kind of technological laboratories. It has proofed to be specially useful in contexts where on site teaching is not possible or the resources are limited.

The study presents a qualitative analysis of the different types of users of the framework, that is, students, teachers and researchers. Their evaluations show positive results that support the continuity of the development of the platform and its use in different types of laboratories.

The next step in this research is focused on formalizing several practical sessions with a higher number of students in order to observe, analyze and try to improve the monitoring system. This system should offer the teacher valuable information about the students taking part in the practical sessions.

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