Online laboratories supported with virtual reality for higher education

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Abstract. Online laboratories have become an alternative solution for the development of the practical component of subjects of higher education academic programs in settings in which physical access is difficult in person. In particular, emerging technologies such as virtual reality enhance the implementation and integration of software applications that allow the user to observe a three-dimensional scenario causing the feeling of being immersed in it. On the other hand, in a complementary way, the universal diffusion and use of mobile communication devices allow to have scenarios in which students through Smartphone cameras access virtual reality software applications giving the feeling of being immersed in a real context. Regarding the central scope, this work describes a method for the design and implementation of software applications that allow the virtualization of laboratory practices in subjects of higher education academic programs. Additionally, as a test, a virtual reality application was implemented that simulates a laboratory practice of the advanced topics in software engineering course of the systems engineering program of the Universidad de Pamplona, Colombia. Finally, measures of perception of emotional variables such as stress, concentration, commitment, attention and focus were taken through an instrument to a sample of the students of the course regarding the interaction they registered when interacting with the technological product. In conclusion, it can be said that through virtual reality, technological solutions can be implemented for laboratory virtualization in emergency scenarios such as the development of the teaching-learning process through technological mediations.

1. Introduction

Online laboratories and virtual reality are two concepts that have gradually increased their impact on education. Virtual reality-supported online labs offer a practical, motivating, and engaging way to teach students in higher education [1]. This type of software application offers a high number of advantages in higher education settings compared to traditional laboratories [2]. Online laboratories are software applications that allow the student or researcher to carry out experiments from a computer or mobile device, such as tablets or mobiles [3]. In a complementary way, through the review and analysis of literature it has been possible to establish the benefits that online laboratories bring to higher education, especially in the areas of Engineering and Sciences [4]. In the same way, online laboratories are characterized by presenting a series of benefits such as spatial and temporal availability, security, the extent of scarce resources, accessibility, the ability to be shared by several institutions and the motivation of students when interacting. with this type of resources [4].

On the other hand, in terms of how to use online laboratories, for a student to interact with these resources, they must download or access the laboratory software through which they can interact with
the immersion scenario of the laboratory through the Smartphone camera or virtual reality glasses. However, one of the problems identified in the literature review is the integration of online laboratories to the learning management system (LMS) [5], which are software tools that are intended to make available to students. students the contents, resources, activities in e-learning systems.

However, the integration of online labs and LMS can become a complex problem; some solutions have opted for the use of standards to allow the reuse of online laboratories in different LMS [6], while another trend is the creation of dedicated solutions that allow communication between the online laboratory and the LMS.

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In this work, a method of design and implementation of online laboratories supported in virtual reality has been defined that takes into account teaching, pedagogical and technological aspects in order to create quality online laboratories. Additionally, in the final part of the method the dedicated solution for integrating the online laboratory to an LMS is defined.

2. Integration of online laboratories with learning management system

Systems integration is a software engineering work area whose scope is interoperability and effective communication between two software systems so that they can be used in an integrated way by the end user. Specifically, initially there are online laboratories as a software system supported by virtual reality and in the second instance there are LMS that are learning management systems that share content, activities and resources among students, teachers and tutors.

Over time, integration solutions have been identified between online laboratories and LMS, some of them have focused on dedicated technological proposals [8] and others have used standards such as shareable content object reference model (SCORM) [9-11] or learning technology interoperability (LTI) [12,13]. In particular, this work describes as an integration strategy a dedicated technological proposal based on the provision in the cloud of the APK for the installation of the online laboratory so that the student can download it to their mobile device and later through the device's camera they can interact with the augmented reality software application.

3. Research methodology

Descriptive research studies a phenomenon under natural conditions without considering hypotheses [14], therefore, in this project it has been defined to use the type of descriptive research in order to specify the phases that structure a method for the construction of online laboratories supported in virtual reality. In a complementary way, the strategy to integrate the online laboratory application to an LMS such as Moodle is described.

Figure 1 shows a general view of the method for the construction and integration of online laboratories. Specifically, the activities to be executed in the design and implementation of online laboratories supported with virtual reality are described. In the first instance, the scope of the online laboratory must be identified and the information to support the content of the laboratory must be collected. In the second instance, how many scenarios are going to structure the laboratory must be identified and, in a complementary way, for each scenario the interfaces and interactions of each scenario must be specified. In the third instance, the information to be incorporated in the front, back, right and left panels must be specified. In fourth instance, the objects, texts, audios and animations
must be created. In fifth instance, the component integration must be executed and finally the application must be integrated into the LMS.

![Diagram of online laboratory construction process]

**Figure 1.** Method for the construction of online laboratories.

### 4. Results

This section describes the result of the application of the method in the construction and integration of a laboratory practice supported by virtual reality for the subject Advanced Topics of Software Engineering in Higher Education and the process of integrating the online laboratory into the LMS Moodle.

The first activity in the application of the method is the identification of the scope of the laboratory, the selection of the theoretical foundation that supports the practical activity, the identification of non-functional requirements of the software and the characterization of the students who will use the laboratory. The scope of the laboratory is to develop the modeling competencies of the Requirements Engineering unit, the theoretical base corresponds to the conceptualization of requirements, the categorization of requirements, the requirements process. In a complementary way, the implementation technology was defined with the Unity engine complemented with VUFORIA and the LMS Moodle to test the integration. Finally, the characteristics of the laboratory's target population were identified, particularly aimed at students aged 19 on average, with high knowledge of computational devices and tools, with previous skills in systems modeling.

The second activity corresponds to the identification of scenarios, design of interfaces and interactions. In particular, three scenarios were identified, the first has as its scope the knowledge of the foundations of requirements, the second has as its scope the knowledge of the construction process of the functional model and the third scenario the development of a practice of requirements of a case study. The selected interfaces correspond to the display of the requirements foundation in the front, left and right panels for the first scenario; for the second scenario, the interface was specified according to the characteristics of the use case diagrams of a UML tool; finally, for the third scenario, the interface was specified through the elements that are incorporated into a use case diagram of a UML tool. Regarding interactions, it was specified that the way students communicate with the application is through the buttons on a remote such as XBOX.

The third activity, panel design, seeks to identify a way for the user to access the information. In a complementary way, it seeks to develop a guide on the controls that will allow the user to interact with the system, when it is immersed in the application. According to the needs of the laboratory, the information was organized in the following way for each of the panels of the scenarios.
Figure 2. Panel design of the scenarios.

Figure 2 shows a diagram of the structure of each of the panels that make up the immersion scenarios of the online laboratory, which in their design were supported by usability heuristics for software applications with virtual reality. The front panel houses most of the interactions and development of the laboratory, this is done because it is the first panel with which the student will have visual contact. This will have the Use Case Diagram, which will appear as each of the buttons is interacted with; the left panel is designed with a guide image which allows the user to know the actions that correspond to each button, so that he can navigate within the scenario options. The right panel is designed by the types of associations, with the objective that the student takes these definitions into account when analyzing the functional model that is presented according to the example (scenario) in which they are at that moment; in this case, the back panel will not contain information, but it is part of the design that you want to have in the development of these applications in order to simulate a classroom. The fourth activity, development of objects, audios, texts and animations includes the educational material development that will be found in each of the panels:

Front panel: Made up of the scenarios that contain the most relevant content for laboratory practice; In particular, the objects that make up the Use Case Diagram are encapsulated. Both the created objects and the text will belong to the same panel, but according to the action that the user executes, the text or the diagram will be visible.

Left panel: This panel is structured with a guide image that allows the user to know how to navigate between the options of the scenario in which he is immersed. It should be borne in mind that, if it is required to insert an image, text, button, panel, among others, it is necessary to create a Canvas, which is the area where all UI type elements must be. When creating a UI element such as an image, a Canvas is automatically created if one does not exist in the scene yet, because this is an abstract space to which it must belong. This is shown as a rectangle in the scene view. Also, the Canvas uses the event system object to help the message system detect errors.

Right panel: This panel is structured with the types of relationships, having the function of serving as support material in the analysis and development of functional modeling competencies of the diagram proposed in the scenario.

The next step in this activity consists of creating each of the audios and animations that will be executed when the user wishes to interact with the system. The fifth activity, component integration, consists of assigning each animation to its respective object, as well as creating scripts in C# language to recognize and configure each action; the sixth activity, integration of the app to an LMS, the apk was uploaded to the cloud and a step-by-step guide was made to learn about the installation processes and uses of the application, specifying each of the elements that are required to interact with the app.

Figure 3 shows the architecture of the dedicated integration solution between the online laboratory and the LMS that makes the activity that the online laboratory will contain at the disposal of the students to carry out the practical activity remotely. Specifically, the designer places the APK of the online laboratory in the cloud so that it can be downloaded by the students and later develop the laboratory practice. On the other hand, the teacher places the guide for downloading the app and the virtual reality practice guide as a resource in the course in Moodle.
Figure 3. Architecture online laboratory integration with LMS.

Regarding the analysis of similar research, proposals have been identified that have as their scope the description of methodologies for the construction of laboratories of any type with the particularity that they are generic and with a marked orientation towards pedagogical aspects. Specifically, in [10] the phases of a methodology for the construction of online laboratories are described, which is structured in the identification of objectives and competencies, design of experiments, technical decisions, laboratory design, design of the lesson plan, related resource design, implementation, testing and debugging.

The added value of this methodology lies in the fact that it is oriented to a specific category of laboratories such as online laboratories supported by virtual reality and can be extended to online laboratories implemented with vision technologies. In a complementary way, the methodology integrates the description of a particular dedicated system for the integration of online laboratories with LMS such as Moodle.

5. Conclusions

This paper presents a methodology for the design, implementation and integration of online laboratories supported with virtual reality; this methodology presents the added value of being able to be extended to online laboratories supported with vision technologies. In a complementary way, it describes a solution dedicated to the problem of integrating online laboratories with LMS by means of a deployment diagram. Online laboratories have become an efficient alternative to develop practical activities for curricular designs in higher education courses, especially in the field of engineering. In particular, it is evidenced that the use of virtual reality technology in the construction of online laboratories allows a solution to the problem of developing the practical activities of engineering courses in higher education.

According to the research carried out, it can be affirmed that the incorporation of virtual reality in the development of online laboratories favors the teaching-learning process in different educational environments such as: primary, secondary, and higher education. It was possible to implement the methods for the construction of online laboratories with virtual reality, and as a result a software application was obtained that function as support material for the design of the use case diagram (functional model) of the advanced topics of software engineering.
According to the results obtained on the characteristics of the software: usability and navigability, it is concluded that both applications have a simple interface and with enough information so that their use is involved in the student's teaching-learning process. The analysis developed through the application of the diagnostic tool on affective variables, allows us to deduce that the application of virtual reality causes in students greater interest, commitment, relaxation, excitement and less stress in the interaction with online laboratory-type software applications with virtual reality.

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