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Definition of a Smart Laboratory Learning Object compatible with Online Laboratory Management Systems

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Abstract:

The Virtual Learning Environment (VLE) or more specifically the Learning Management System (LMS) can report to an Online Laboratory Management System (OLMS) information about the student's progress in the class. Based on that information and teacher definition of parameters, the Smart Adapter module retrieves the laboratory activities and assessment content from the VLE and connects them with one or more online laboratory experiment stations to create the Smart Laboratory Learning Objects (SLLO).

The SLLO components include class materials, lab activities, assessment information, student information, and information about access to the online laboratory experiments. These learning objects are managed by the OLMS. Additionally, the teacher can compose Smart Laboratory Learning Objects using a laboratory composer module in the OLMS.

The Smart Laboratory Learning Objects (SLLO), has been defined based on the previous definition of the Laboratory-based Learning Object (LLO) and the one proposed in the Lab4CE. The proposed SLLO integrates the core components of the proposed architecture of the IEEE 1876 - 2019 Standard for Networked Smart Learning Objects for Online Laboratories.

The proposed Smart Laboratory Learning Object (SLLO) is defined specifically for laboratory experiences. In this sense, different students will have access to different activities that, in some cases, can use the same laboratory experiments exhibiting different levels of complexity in their interactions and requiring different levels of knowledge for its operation. An example of this is a skilled student using a more challenging experiment and activities, while less skilled students will see a simpler version of the experiment with different activities that evaluate more basic concepts.

This paper proposed the definition of the SLLO architecture that can be used as part of an online laboratory management system OLMS. An example of a SLLO implementation is presented to show the capabilities of this architecture.

1. Context of Online Laboratories

This section presents some works that are part of the state of the art for online laboratories used in education, including virtual, remote and hybrid laboratory implementations.

The Virtual Instruments Systems In Reality (VISIR) project [1] develops online laboratories specifically in areas of Electrical and Electronics Engineering, including hands-on, virtual, and remote experiments. The VISIR experiments include: protoboards, sources, signal generators, meters, oscilloscopes and components (resistors, capacitors, inductors, diodes etc). All the experiments can be remotely operated through the Internet. This characteristic allows users from all over the world to use the laboratory 24/7. It is considered a powerful tool for cooperation among institutions. VISIR was developed by Blekinge Institute of Technology in Sweden (BTH).

In 2019**,** Knox et al [2], proposed the use of virtual reality to offer a more realistic experience to students that use virtual laboratories. In this work the laboratory equipment was modeled in 3D and all of the controls of the real version were mapped in the virtual 3D model. This allows the user to have an experience that additionally to the development of the hands-on experience applying the topic concepts, it also can be considered as professional certified training on the manipulation of the real equipment.

Additionally, in 2019, Zapata-Rivera [3] proposed an innovative model to offer remote access to control expensive lab measurement equipment. This model uses a controller with internet capabilities that receives the user data (signal to be measured) and commands (measurement to be made) and a computer program running in a cloud server receives this information and redirects the request to an available device that processes it sends the results back to the user browser screen.

Labster [4] develops interactive virtual laboratories including simulations based on mathematical algorithms that support open-ended investigations. Their products are also developed including gamification elements such as 3D environments, storytelling and a scoring system. The laboratories are being used for different universities including Harvard, MIT, Stanford among others. Recently they have developed virtual laboratories using virtual reality components for interactive experiments using simulated data. Some learning topics in the VR labs are biodiversity, basic electricity and chemistry, evolution, biology, among others.

2. Architecture of Smart Laboratory Learning Object

The Smart Laboratory Learning Objects (SLLO), has been defined based on the previous definition of the Laboratory-based Learning Object (LLO) [5] and the one proposed in the Lab4CE [6]. The proposed SLLO integrates the core components of the proposed architecture of the IEEE 1876 - 2019 Standard for Networked Smart Learning Objects for Online Laboratories [7].

2.1. Definition of Smart Laboratory Learning Object (SLLO)

The Smart Laboratory Learning Object (SLLO) is proposed as a package that can be deployed independently on a local computer or web server and provides access to a laboratory experience including one or more activities and access to local or remote resources.

The SLLO can include class materials, examples, laboratory activities and the access to the hardware experiments needed for that specific lab. Reporting capabilities and learning analytics can be added through the integration of Experience API (xAPI). The user interactions and administrative information is collected and stored in the Learner Record Store (LRS) in the form of xAPI statements and it is ready to be accessed by the VLE or any other platform. The system supports different configurations of LRSs to comply with the stakeholders required privacy and security definitions. Figure 1 presents the components that interact together with the SLLOs objects, virtual lab activities are available as resources as well as remote laboratory stations. The Online Laboratory Management System OLMS or a generic Virtual Learning Environment Such as a Learning Management System LMS will serve as the deployment system and also as the host of the student interactions.

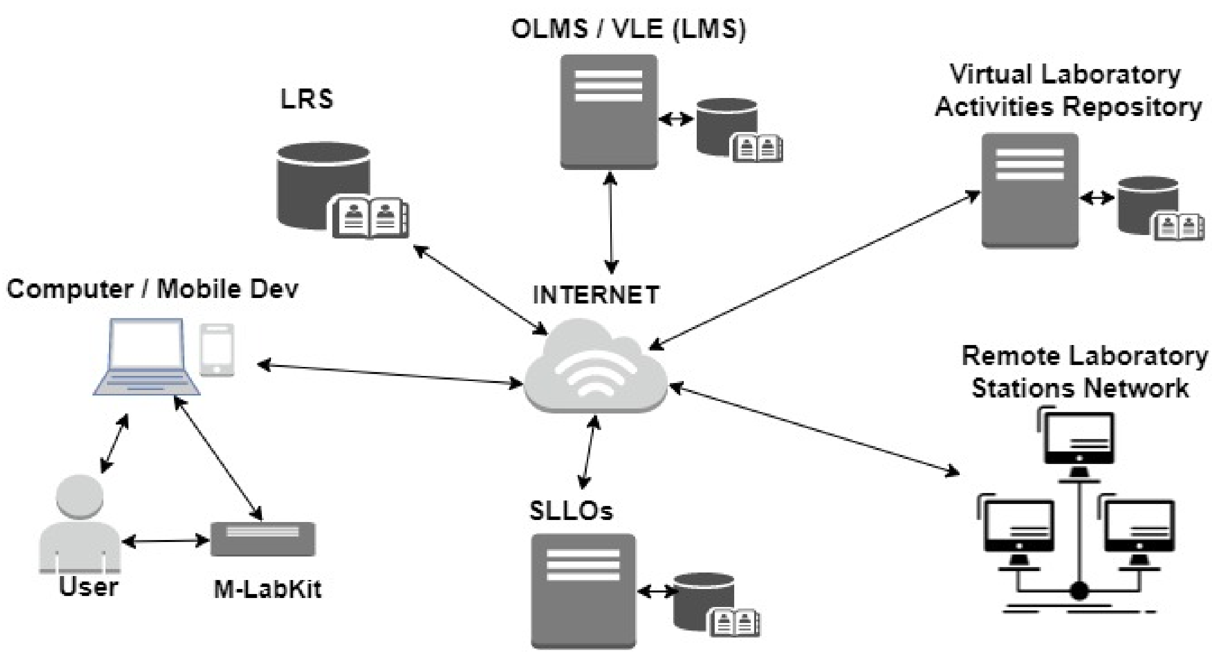

Figure 1. Deployment Diagram of SLLOs interactions with OLMS Systems, virtual labs and remote laboratory stations

2.2. SLLO Metadata

Since the online laboratories are a type of learning object, its defined metadata uses some of the fields defined by LOM (Learning Object Metadata) [8] and add new fields that are specifically related to online laboratories such as: title, type_of_lab a, activity(s), among others. Table 1 presents the data that the professor who creates it gives us so the system can classify it in one of the galleries.

Field Name	**Field data type**	**Description**	**Mandatory / Optional**
title	String	Unique title for the lab	Mandatory
purpose	String	Description of the purpose of the lab	Optional
topic(s)	String[]	Topics covered in the lab	Mandatory
type_of_lab	String	Virtual, Remote, Hybrid	Mandatory
connectivity	String	Local, Online	Mandatory
synchronicity	String	Synchronous (Real time) or asynchronous (differed)	Mandatory
activity(s)	String[]	Description of activity(ies) to do	Mandatory
assessment	String[]	Description of assessment	Optional
deliverables	String[]	Description of outcomes	Mandatory
creation_date	date	Date created in the OLMS	Optional
publishing_date	date	Date published in the OLMS	Optional
prereq_lab	String[]	Lab prerequisite needed	Optional
lab_duration	int	Amount of minutes	Optional
difficulty	int	Easy:1, intermediate: 2, hard:3	Mandatory
lab_stations	int[]	Number of lab stations available	Optional
visibility	boolean	Visible to students:1, no visible to students: 0	Mandatory
xapi_enable	boolean	Tracking enabled or dissabled	Mandatory

xapi_actor	String[]	Tracking actor (student, teacher, lab manager, remote lab)	Mandatory
xapi_lab_objects	String[]	Tracking objects (lab station name, activity name, component of lab station, etc)	Mandatory
xapi_lab_verbs	String[]	Tracking verbs (tested, interacted, scored, attempted, etc)	Mandatory

Table 1. Metadata of SLLO

The SLLO will exhibit all the integration features if it is deployed on an Online Laboratory Management System (OLMS) or Learning Management (LMS) that complies with the Standard IEEE 1876 Networked Smart Learning Objects for Online Laboratories. This standard proposed a layered model for the information and data separation, from devices up to user layer. Figure 1 presents the IEEE-1876 standard proposed layers.

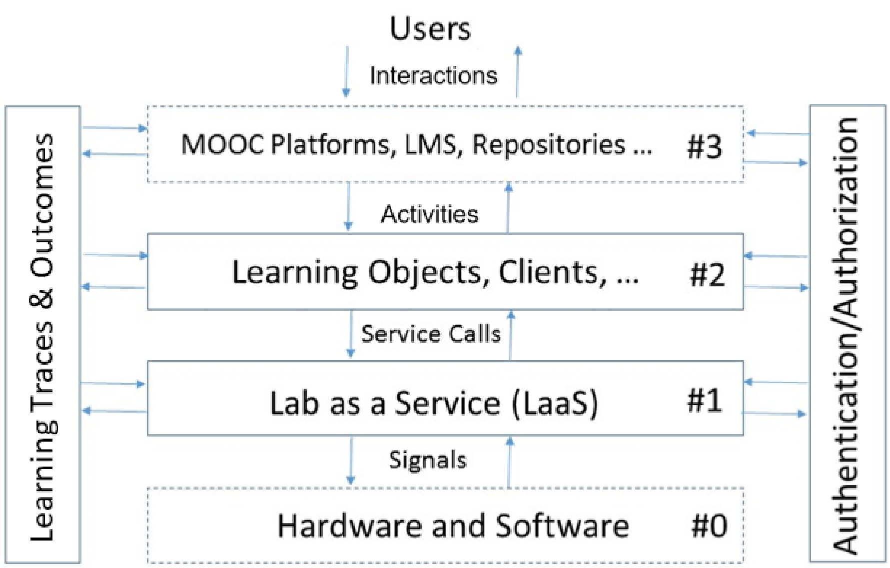

Figure 2. IEEE-1876 Standard architecture layers [7]

3. Implementation of Online Laboratory Experiences based on SLLO Architecture

This section describes three online laboratory experiences that make use of hybrid laboratories that combine virtual components, access to a real remote laboratory station and offers the possibility of interacting through mobile laboratory kit in which students of Digital electronic implement their lab assignments.

These laboratory experiences have been deployed over SARL Smart Adaptive Remote Laboratory platform [9], this system was implemented as a testing infrastructure for online laboratories that support auto-adaptation of functionalities, tracking capabilities through the use of xAPI and support for educational user roles [10].

The Hex-bugs remote laboratory station was developed to implement laboratory experiences in different contexts, such as programming, electronics, logic design, among others.

To develop the Hex-bugs remote laboratory station, a set of two remote controlled Hex-bugs Battle Spiders were used (cost 50$ USD) [11], see Figure 3. A set of infrared (IR) receivers and external battery pack with wireless chargers for each Hex-bug, allows hardening of the laboratory by not having to replace batteries and flexibility in the scenarios created. The remote controller of each robot has been connected to the Raspberry Pi3. Five GPIO pins were used, two for forward and backwards movement, two more for left and right rotation and one more for triggering the infrared beam.

Figure 3. Hex bug lab station

This laboratory experiment can be controlled directly from the web interface using the computer or mobile device or also using the student laboratory implementation kit. It is an example of a hybrid laboratory utilizing mobile, remote and virtual laboratories and uses multi-threading in the Raspberry Pi to control movements/rotation and control the infrared/detection target hit. Different scenarios have been designed to demonstrate the flexibility of the online laboratory.

3.1. Logic Design Laboratory Experience

For this case, the goal is to control the robot and select a specific element in the scene using the IR gun built into the robot, the set of elements displayed is previously defined in the activity.

A boolean expression is given to the students and it can be generated by the system, by the teacher or input by the user to be validated as right or wrong based on the input on the user breadboard. The students have to implement the Boolean expression with the logic gates chips in a circuit build using their lab kit. Once the students finish the implementation of the circuit, they will connect the lab kit through a signal interface device to their device (computer, tablet, cellphone) to interact with the virtual laboratory. A proposed scenario is composed of a robot working to provide support collecting supplies to attend an emergency. The boolean expression corresponds to the set of supplies to attend an emergency mission. The robot mission is to select the item in the order specified. If the students implement the circuit correctly, the Hex-bug will collect the items in orden and the mission will be accomplished.

The scenario is augmented with virtual elements that are displayed on the wall and floor, attached to each virtual image is one of the IR receivers.

Figure 4 presents the digital scenario that is integrated as Augmented Reality AR element during the real time control of this hybrid laboratory. After its collection the hex-bug must be maneuvered to the charging location to complete its mission successfully.

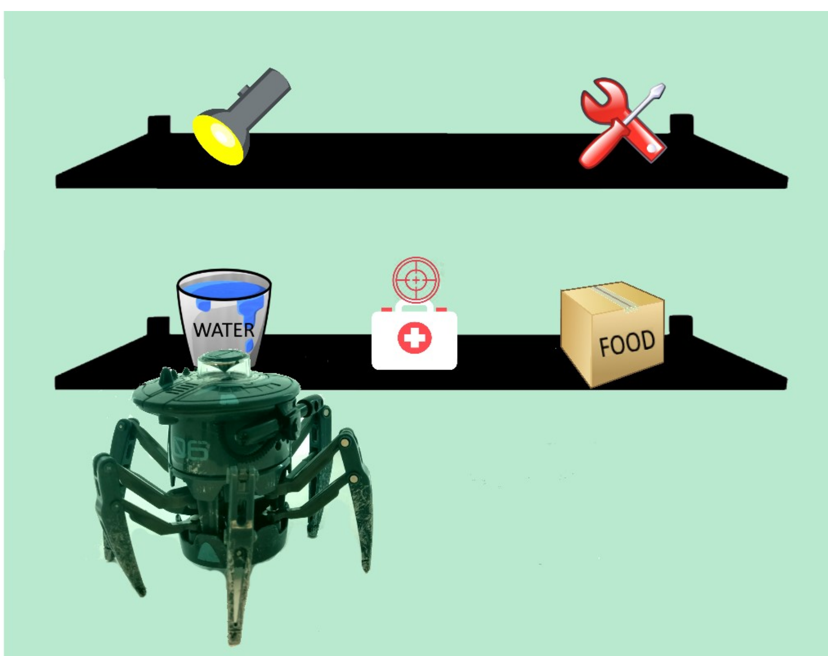

Figure 4. Hex bug mission AR scenario

3.2. Introduction to Electronics Laboratory Experience

The goal is to control the speed and the IR gun of the Hex-bug. For this activity, the students should use a non-inverter configuration of an operational amplifier with variable gain to control the speed and a simple configuration with a switch to turn on and off an LED for mimic the gun shoot.

Similarly, to the previous activity, the students have to do a real implementation in their lab kit and then interact with the remote lab through the use of a signal interface device. The proposed scenario has the robot working to reach a place in a specific amount of time. In the route, the robot will find targets that it should shoot, then it should slow down, shoot and continue.

In this case a hybrid environment with augmented reality will be used to show the route, targets, the destination and the speed and time expended.

3.3. Programming Laboratory Experience

As part of the programming laboratory experience the following activity was defined: In this activity, the student will control the robot to walk in a given path. The path could be generated by the professor, or by the system preset. Additionally, the robot will stop in specifics points of the pat and shoot to a target. The student should then code the movements of the robot using python programming language.

The students will receive the number of steps in each direction and the direction where the target will be located in each spot.

Similarly, to the previous activities, a hybrid environment with augmented reality will be used to show the path and targets.

4. Logic Design Laboratory Experience SLLO Metadata

Table 2 shows the SLLO used for the Logic design activity presented in section 3.1.

Field Name	Content
title	GetSuppliesMission_lab
purpose	Design and implement a Boolean expression using logic gates to control a robot in a getting supplies mission
topic(s)	Boolean expressions

type_of_lab	Hybrid
connectivity	Online
synchronicity	Synchronous
activity(s)	Fulfil Kmap; determine the minimum Boolean expression; design the circuit using AND, OR, NOT gates; design the circuit using all NAND gates; implement the all NAND circuit in the lab kit; connect the lab kit online to test validity of the implemented lab versus the remote lab.
assessment	If the activity is completed during the defined period the system reports a passed value, otherwise it will report not_passed
deliverables	Kmap; minimum Boolean expression, circuit using AND, OR, NOT gates; circuit using all NAND gates; implemented circuit in the lab kit; test the circuit with the remote lab
creation_date	10/14/2019
publishing_date	11/11/2019
prereq_lab	color_coding_lab
lab_duration	45 min
difficulty	2
lab_stations	1
visibility	1
xapi_enable	1
xapi_actor	studentID, LabKitNumber, HexBug
xapi_lab_objects	Hexbug1, HexLab, supply 1, supply 2, supply 3, supply 4
xapi_lab_verbs	Scored, attempted, completed, interacted, collected

5. Conclusions and Future Work

This experience open possibilities for integrating different types of laboratory resources and to give to teachers and students a more flexible and integrated environment of online experimentation

The integration of student’s laboratory kits allows the development of hands-on skill in students as well as the possibility of offering a more interactive experience to blended or totally online groups of students.

The SLLO definition is the first step in the path of generating interoperability between online laboratory systems, learning management systems and laboratory resources.

More implementations are in process of development and a validation of these hybrid online laboratories with the integration of them to a real laboratory class with over 150 students is also in process at Florida Atlantic University during 2020.

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