Physics-Electronics Practical Work Model Accessible and Manipulable Remotely via the Web

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***Abstract* - Today, hands-on laboratory work is the most effective way to develop skills in the field of STEM (Science, Technology, Engineering, and Mathematics). However, this practical work usually takes place in local laboratories, which poses a problem in the context of higher education marked by the massification of students. Researchers have proposed solutions for remote practical work for computer science courses (programming, networking) by using screen sharing, improved functionality of LMS platforms, virtualization and the cloud. However, remote practical work in the field of physics-electronics is very limited and does not take into account the flexibility and simultaneous access to practical work benches. In this paper we propose a model of physics-electronics practical work accessible and manipulable remotely via the web. To illustrate the relevance of our model, we propose a device to detect a laser signal via an optical fiber controlled by a Raspberry pi from our web platform.**

Keywords – E-lab; Physics-electronics; Internet of things; Flask; Remote practical work via the web

I. INTRODUCTION

Senegalese universities, like those in the South, particularly in sub-Saharan Africa, are experiencing increasing difficulties in providing their students with a suitable practical work (PW) environment. The available infrastructures, especially the local laboratories for practical work, are largely insufficient to accommodate the high number of students. These difficulties are linked to the increase in the number of students, the cost of equipment and often to the non-existence of practical work done by teachers, to the point where practical work is no longer done in certain STEM (Sciences Technologies Engineering and Mathematics) disciplines. This situation weakens the field of STEM which requires specialized skills and this requires a systematic revival of practical work sessions in STEM training. Today the question of carrying out practical work at a distance in the field of STEM is raised and becomes a real research problem [1][2]. In the research, authors have proposed solutions for remote practical work in the field of computer science (programming and networking) through the use of distance learning platforms [4][5] and emerging technologies especially in the field of cloud [3], virtualization [15] and the use of telecom network protocols [6][7][8].

In this paper, we are interested in remote practical work in physics-electronics, which is one of the STEM domains for which the proposed remote practical work solutions are very rare. For this purpose, we propose a model of remote practical work that manipulates from a web browser physical-electronic devices connected to IoT objects. This will allow to mutualize the resources of laboratories in order to have a wide range of benches of simulations and experiments. This will also participate in maintaining a large network of collaborators, and consequently guarantee a maintenance and a continuous improvement of the quality of the experiments/simulations.

To bring the proof of our concept, we will set up a PW bench dealing with the detection of the signal intensity of a laser via optical fiber controlled by a Raspberry pi. Thus, we give the possibility to the learners to manipulate via the web the Raspberry which controls and drives the practical benches.

To carry out the work, we present in section 2 related work on remote practical work PW solutions. In section 3, we present our model of remote PW access for practical work benches that need to be connected to connected objects. In section 4, we present a device for detecting the intensity of a laser via optical fiber accessible and manipulable via the web. In the section 5, we present the results of our implementation.

II. RELATED WORK ON DISTANCE LEARNING IN PHYSICS AND ELECTRONICS

Remote laboratories come in various types [9][10] and are nowadays an essential means for the correct performance of remote practical work (PW). They allow solving the problems related to the realization of the practical works that are an obligatory component of the STEM learning and especially in the field of physics-electronics. During this last decade, many solutions resulting from research works [11][12][13][14] have emerged to fill the lack of pedagogical infrastructures in front of the massification of learners which increases from year to year in the Senegalese public universities in particular and in Africa in general. In the same way, we had to propose some solutions as a contribution to the numerous challenges to be taken up in order to have an effective educational system for the realization of practical work at a distance. In [15] and [16], we have set up a virtual environment based on Cloud Computing that gives access to virtual machines and a web platform integrating a video conferencing solution based on WebRTC technology [16] for synchronous monitoring of the practical work. The web platform through which users authenticate themselves to access the virtual resources provided by the cloud, allows teachers to schedule lab sessions and share materials that will be accessible by students while remaining on the same platform to perform computer science lab sessions. Subsequently, in [3], we proposed a container-based remote lab environment as a replacement for virtual machines to optimize resources, and provide a collaborative and easy-to-access lab interface. This system is mainly based on Docker technology [3].

Other researchers have proposed some solutions to realize practical work based on simulation [17][18] and the Internet of Things [19][20][21] among others. In [18], the author tries to provide solutions to many pedagogical and technical problems often encountered in higher education distance learning courses. These problems have been identified and reported by the teachers in charge of the courses. All the implemented solutions have been thoroughly discussed between developers, teachers and learners; this explains the methodology adopted in the [18]. However, the contribution of the paper is mainly based on the simulation of educational materials.

An Arduino remote lab is proposed in [20] to provide support for e-learning experimental environments in the Internet of Things IoT domain. It provides quality online education programs. The authors in [21] proposed an Internet of Things based remote laboratory that enables experiments in the field of moving image analysis. This paper is carried out in the context of the European project IoT4SMEs and aims at improving distance learning. The paper in [22] presents a technique for motivating students in learning digital electronics and improving practical work in this field. The proposed system gives learners the possibility to perform/retake some experimental work at home, which increases their motivation. This system is mainly based on the Moodle distance learning platform and a prototyping board that includes the FPGA board.

However, most of the proposed solutions are largely based on simulating teaching materials and/or remote access software that teachers and learners have to install on their machines beforehand. This is a good practice because it is better to start with simulation before attacking the physical components which are often very sensitive. However, it would be more interesting if these solutions would allow the learners, after having carried out the PW by simulation, to carry them out on physical material while remaining remotely and on the same platform which centralizes all the process of correct realization of a PW.

It is in this perspective that our contribution will focus on solutions to improve the remote practical work in the field of physics-electronics. The proposed solution is based on the Internet of Things and the Flask web technology.

III. PROPOSAL FOR AN IOT-BASED PHYSICS-ELECTRONICS LAB MODEL ACCESSIBLE VIA THE WEB

A. Proposal for a PW model

The proposed model is structured in three levels: the e-lab (PW material), the web/LMS platform and the users. It is illustrated in figure 1.

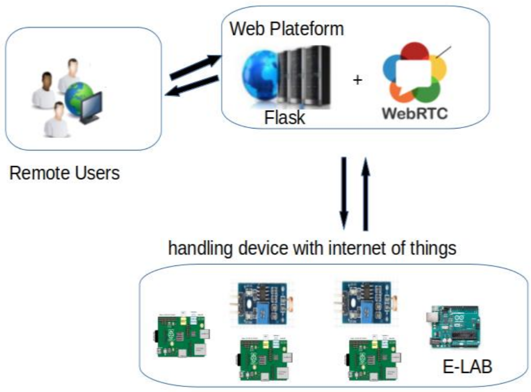

Figure 1. Remote practical work model in physics-electronics

- E-lab:

  This first layer is the basis of the proposed system. It contains the physical and virtual equipment necessary for the realization of remote practical work. These equipments are essentially composed of classical laboratory materials, IoT objects for remote manipulation, a camera for remote visualization of the manipulated objects, a configuration and control system for the IoT objects and a database for storing the data from the IoT objects. The equipment is arranged in the form of practical work benches.

- WEB/LMS Platform

  The second layer is a web platform that serves as an interface for users to access, after authentication, the educational resources located in the remote laboratory. The web platform allows, among other things:

  - to plan practical works and to reserve benches of practical works (teachers);

  - to consult the supports and instructions of the practical works planned by the teachers (learners);

  - to carry out simulations on virtual objects before starting the manipulation on real objects at a distance;

  - to visualize via a simple browser the real objects manipulated remotely from the laboratory.

- Users

  The third layer is the users, which are the teachers, the learners and the administrator.

IV. ADAPTATION OF OUR MODEL FOR A TYPE OF PRACTICAL WORK BASED ON THE DETECTION OF THE INTENSITY OF A LASER VIA AN OPTICAL FIBER

A. Presentation of a type of practical work on the detection of the intensity of a laser via an optical fiber

In this part we will present a typical case of realization of a device of detection of the intensity of a laser via an optical fiber in the laboratory of the department of physics of the University Alioune Diop of Bambey. This practical work is realized by the physicist Dr Papa Lat Tabara Sow co-author of this paper. The architecture of the PW is presented in figure 2.

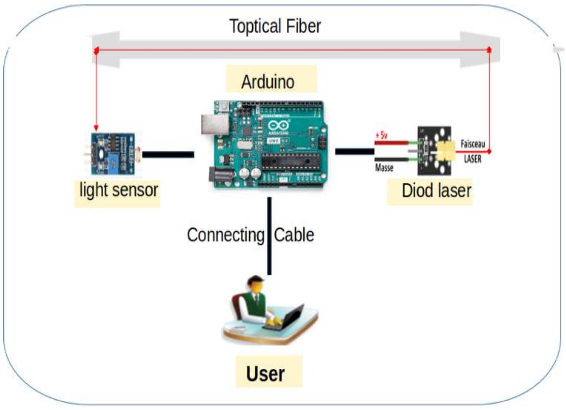

Figure 2. Initial architecture of the practical work with Arduino

Initially, the learners realized the PW using an Arduino board as a control acquisition center, an optical fiber as a waveguide and a laser that plays the role of information transmitter. To carry out this PW, the learner must first install the Arduino technology on the machine in which the Arduino board must remain connected to upload the scripts (figure 3). This obliges the learners to be gathered in the same room of PW where the material is.

This is a project of realization of a device of detection of the intensity of a laser. Its general objective is to show the students the vast field of application of lasers and to put into practice concepts such as pumping, population inversion and laser cavity learned in class. Specifically, it will enable learners to:

- Carry out the transmission of a digital signal by laser via an optical fiber;

- Discover and experiment an application of lasers in the field of telecoms;

- Discover the use of an Arduino board to drive a light source and sensor;

- Recall and experiment with the physical effects involved: total reflection for light guidance.

However, the realization of this type of practical work requires a physical presence in the laboratory and is not flexible for not only other types of practical work but also for a large number of learners wishing to work in collaboration. Therefore, in the following we will propose a more suitable lab architecture.

B. Architecture of the type of practical work proposed

The architecture of the PW model is illustrated in Figure 3.

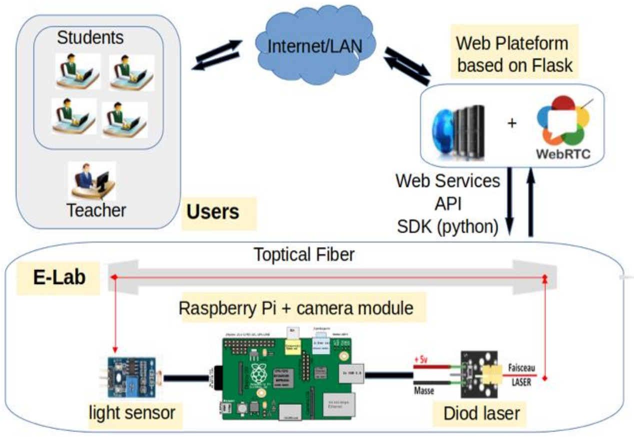

Figure 3. Architecture of the PW of detection of a laser via optical fiber based on the web

The proposed architecture aims to bring ease in the correct realization of the same PW and to achieve the same objectives but with a lot of flexibility, mobility thanks to Raspberry Pi technologies, Web Services and WebRTC for the communication between teachers and learners. For this, we replaced the Arduino board with a Raspberry Pi that allows to control and manipulate the whole device from a web platform. What is interesting here is that the Raspberry itself is remotely controllable from the web platform and can be used for simultaneous access to several learners or other types of practical work. This solves the problem of optimizing educational resources and the massification of learners in public universities. With such a system, the learner will no longer need to install or deploy anything on his machine to perform a practical work. He only needs a simple browser because everything happens on the web platform.

V. RESULTS

To prove the relevance of our model, we have implemented and realized a practical example in electronics about the detection of the intensity of a laser via optical fiber. The laser and the light detector are controlled and manipulated by a Raspberry pi from our web platform as shown in figure 3. To carry out this work, we have deployed the Flask web technology (a python framework) which will serve as our access interface to the implemented IoT device. The following part of the paper shows the different steps of the practical work illustrated by screenshots.

A. Authentication page

We have implemented an authentication mechanism to access the web platform; this allows us to control and secure access to the PW devices set up.

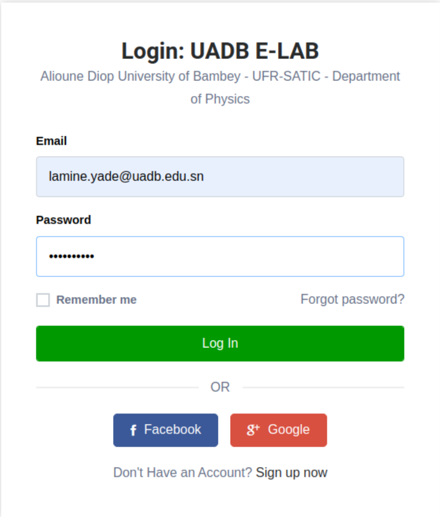

Figure 4. Authentication page

B. Practical work list

After successful authentication, the user has access to the list of scheduled practical work. He can select one of them and click on the Start button to start the lab. This scenario is illustrated in figure 5.

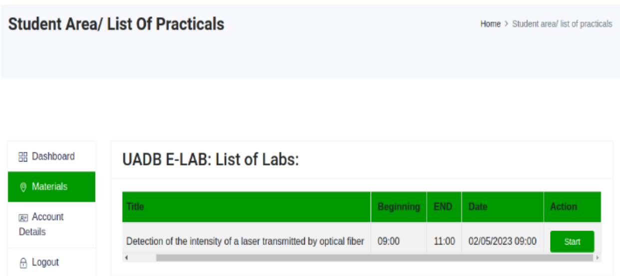

Figure 5. Viewing page for the list of PW

C. PW realization pages

There are several applications, protocols or network services to access and manipulate the Raspberry pi remotely. Among them we can mention vnc, spice, ssh, containers, web ssh (Shellinabox), code-server, among others.

In this paper we have chosen Shellinabox and code-server.

- Shellinabox offers a remote access service to the Raspberry terminal from a browser based on the ssh protocol. It is light and easy to deploy. The following picture shows the access to the Raspberry pi from our web platform set up with Flask using the ssh web protocol (Shellinabox).

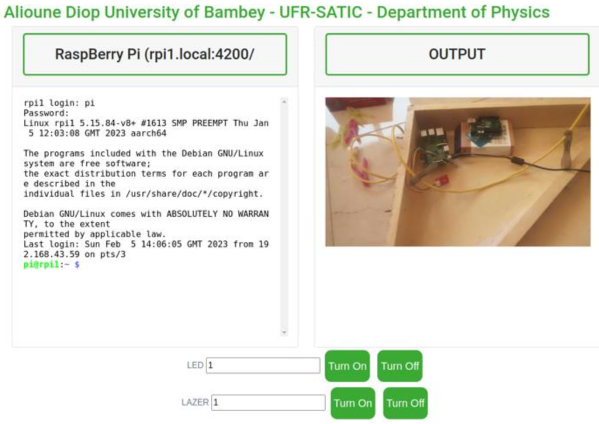

Figure 6. Access to the Raspberry from the web platform with ssh

- Code-server offers a complete remote development environment on Python, C, Java, PHP, JavaScript among others. It integrates a terminal and allows full access to the Raspberry tree. From the same interface, the user can access all the folders/files of the Raspberry, write scripts and execute them on the integrated terminal. Figure 7 shows the page for a practical work with code-server:

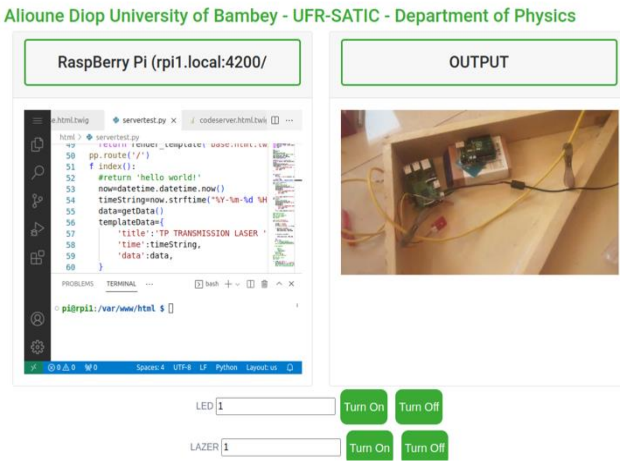

Figure 7. Remote programming on the Raspberry from a web interface

From these two interfaces the user can, on the one hand, install and configure protocols and applications and, on the other hand, write or execute scripts to control the Raspberry GPIOs from the web platform. After starting the python script prepared for this practical work, he can click on the Turn ON/Turn Off buttons to manipulate and control the laser while visualizing the results from the video installed in the lab and displayed in the same page.

VI. CONCLUSION AND PERSPECTIVES

Generally, the practical work in the STEM field more specifically in physics-electronics is done face-to-face in the local laboratory room and does not offer flexibility in the correct realization of remote and collaborative practical work. In this paper, we have shown the possibility of correct realization of remote practical works in this domain by allowing the learners to have on one hand the hand on IoT objects connected to the laboratory device and on the other hand to manipulate remotely these same devices from a web platform configured and adapted to the need of the PW. From the web platform, the learner acts on buttons to manipulate the remote device and can have in return the result of his manipulations visible on the same web platform.

In perspective, we intend to propose a model of mutualization of resources of practical work on real devices of laboratories of universities and institutes in Africa within the framework of a collaboration or a win-win partnership.

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