Demo: Developing a Virtual Remote Operating IoT Lab for Higher Education Research

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***Abstract*—This demo presents a prototype lab developed for research and teaching purposes. Its innovation and novelty rely on the fact that the lab can be operated fully remotely using real, non-simulative, IoT and robotic hardware.**

Keywords—Remote Lab, IoT, Real Time operation, Robotic hardware

I. Introduction

One key lesson learned in recent years is that events that prevent real physical interaction like the COVID-19 pandemic, or climatic events that are limiting travelling, can be overcome by remote interaction and virtual collaboration. However, one key aspect of academic research that remains a challenge is the use of real life embedded, IoT or robotic laboratory hardware for research and teaching. [1]

At the Holon Institute of Technology this challenge has been identified and a program has been established to develop a remote lab that can enable researchers and students to operate directly the lab equipment in a remote (i.e. "virtual") mode.

The lab is in its final prototype. It's expected to be launched as an academic learning environment in a course that will be offered in the coming semester. Assignment examples supported by the tool will be presented in the demo.

Section II describes the guiding principles for usage of the remote lab. Section III provides a brief description of the remote lab to be shown in the demo proposed.

At RTAS 2024 we will provide a hands-on demo of the lab operation showing the versatility of the tool for complex assignments and the challenges to set up the lab.

II. Usage Principles

A. Realistic experience

The laboratory provides an immersive lesson or research experience, it manages content in the cloud, enabling to conduct remote lab experiments, and connect lessons seamlessly for an engaging learning experience to bridge the gap between theory and practice in an accessible, interactive environment. The lab equipment consists of IoT sensors and actuators and robotic equipment as, for example, the connection of an embedded controller board to a sensor shown in Fig. 1.

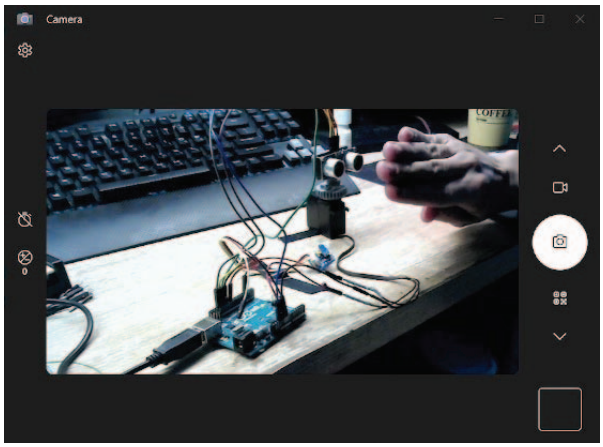

Figure 1. Sample use case for Remote Lab experiment

B. Ease of Use

The ease of use of the control panel is another guiding principle we apply for an effective, yet inviting, experience for students and researchers alike. For example, Fig. 2 shows the remote activation dashboard used by students.

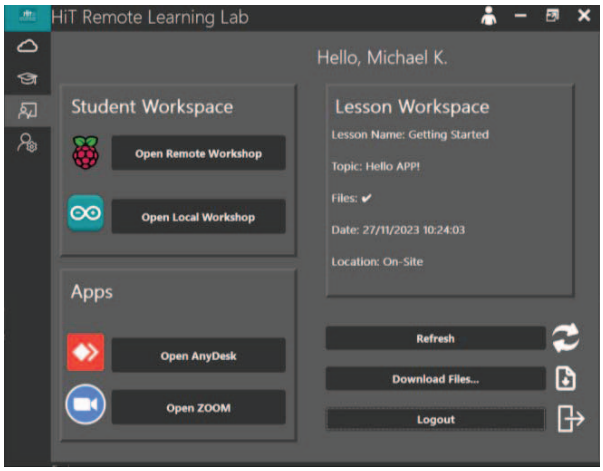

Figure 2. Remote lab student's dashboard

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DOI 10.1109/RTAS61025.2024.00040

It allows control of the lab in either local (physical proximity) or remote (virtual) operation through the following activations:

- Connect to remote lab system: Access remote lab systems to conduct experiments and practical sessions virtually, fostering hands-on learning.
- Connect to local lab system: Utilize local lab resources for practical exercises and experiments.
- View active lessons information: Access information about ongoing lessons to stay updated on curriculum topics and schedules.
- Download additional files from the Cloud: Download additional files and resources stored in the cloud related to ongoing lessons.
- Logout: Safely exit the session when done to ensure the users account the security.
- Open External Applications. Seamlessly access external applications like Any Desk or Zoom for collaborative sessions or supplementary learning.

III. Set up and Operation of the Virtual Lab

A. Remote Lessons Set up

Teachers are able to set up the learning environment of the remote lab using the dashboard. It enables them to create, add, delete or upload lessons to the cloud. Assignments can be created from the simple manipulation of sensors and actuators to the full creation of robotic or IoT environments that can be coordinated and fully remotely operated. Once a lesson and assignment have been defined and uploaded to the cloud, it becomes visible and ready for activation to all remote users.

The physical set up of sensors and actuators still requires, at the present stage of the prototype, the presence of a lab technician that can enable all the defined lab physical resources. This is a "once only" activity that then enables all remote users to virtually operate the lab thereafter. It is planned to do away with this need in the future, as discussed in section III. C below.

B. User Operation

The heart of the system is its remote operation by students and researchers, using the dashboard described in section II. B above. Fig. 3 shows the experiment command dashboard. It enables:

- Hardware control and Script execution: Interact with and control hardware remotely using Python scripts. Execute commands to manipulate hardware components and observe their responses.
- Access lab camera: View live video feeds from the lab's camera, observing ongoing experiments and the behavior of hardware components as shown in Fig. 1.
- Open Python IDE: Create a new script or modify existing ones seamlessly in the integrated IDE.
- Run grapher with real-time options: Utilize the grapher tool to visualize data in real-time, allowing the monitoring and analysis of outputs dynamically.

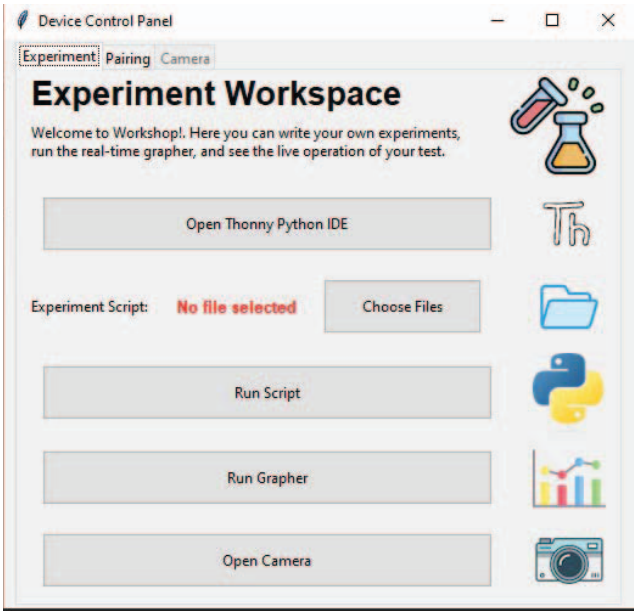

Figure 3. Remote lab operating dashboard

C. Future Lab Development and Research

To make the experience realistic as described in section IIA above, presently we are developing a completely remote operation of the laboratory by implementing an enhanced environment where the intervention of a Lab Technician is not required. Students and researchers will be able to operate all ancillaries like power switches, air conditioning, lightning, heating and room access control remotely. Moreover, a challenging aspect of a realistic experience with a remote lab is the management of exceptions such as hardware, power or communication failures for operators that can be in a different country or even continent, similarly to challenges of Satellite operation [2]. We shall discuss these topics with the audience for future development and improvement of the lab including its applicability for different engineering courses and benefits for follow-up research and collaboration initiatives.

Acknowledgements

We thank Ruth Foraiter of the Faculty of Instructional Technologies at HIT for her support in preparing the material.

This work was supported in part by IDEATION under EIT's HEI Initiative supported by EIT Manufacturing, coordinated by EIT Raw Materials and funded by the European Union.

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