International Conference on Remote Engineering and Virtual Instrumentation

Structured Abstract

REV Conference

A Low-Cost Spectrometry Remote Laboratory

CONTEXT

The Covid-19 pandemic has precipitated the digital transformation in education worldwide and has exposed weaknesses and limitations in laboratory and experimental activities, mainly in the field of engineering. This forced us to provide rapid answers through a change in practice in our removable energy program, from a conventional hands-on classroom experiment to a remote spectrometry laboratory. Furthermore, due to the new on-line education modality, students attending the lectures were not limited to those from a specific campus. In this context, using costly spectrometry equipment that was not adapted to be operated remotely, was not an option. We therefore leveraged our low-cost spectrometry technology to rapidly and successfully deploy a spectrometry remote laboratory.

PURPOSE OR GOAL

The goal of this work is to adapt our low-cost spectrometry technology (which is based on a 3D-printed mini spectrometer and a smartphone) to deploy a remote laboratory as a rapid solution, due to the impossibility of using conventional and costly spectrometers, which work only for on-campus learning. This adaptation was helpful, not only to have several spectrometers available for a higher number of students, but also to allow teachers to prepare asynchronous activities that can be realized without their presence.

Even though we have developed our low-cost spectrometry technology back in 2017, and applied it to several research projects (in the biomedical and industrial areas), the pandemic brought us a new opportunity to apply it in engineering education.

In many solar energy BSc. and MSc. programs, solar spectral phenomena are usually presented rather superficially; there are no specific labs for students to learn how to read spectra, understand solar spectra, colour temperature, and use spectrometers. Thanks to the proposed low-cost remote laboratory, we provide students with technology to remotely operate the spectrometer and analyse spectral phenomena individually (e.g., black body and colour temperature spectra from different sources).

APPROACH

Our low-cost spectrometry technology uses a 3D-printed mini spectrometer which is attached to the camera of a smartphone. The mini spectrometer contains a 100µm slit, a focusing lens which addresses the parallel beam to a 1000 lines/mm diffraction grating. For processing the spectral images obtained by the mini spectrometer, we developed a multi-platform smartphone App (Android and iOS) which can process, visualize, store and transmit spectral data via an internet connection.

To implement the low-cost spectrometry remote laboratory, we had to solve two main issues. Firstly, the baseline mini spectrometer required manual wavelength calibration, i.e, each time that the device was restarted, the user had to visually identify and select reference spectral lines (e.g., using a light source with Hg). This is highly impractical for a remote laboratory that should operate 24/7. Therefore, we improved the spectrometer software for automatic wavelength calibration using a Machine Learning algorithm, which is able to identify the reference lines, and can be ready without user intervention. Secondly, we needed to remotely control both the spectrometer and the devices used for the experiment. For this, we developed a Web Application that allows students to remotely control the parameters of the spectrometer, observe the spectra in real time, measure the wavelengths of the spectra, store the data generated in the web platform, and carry out experiments and practical exercises. The system uses IoT (Internet of Things) devices to remotely control the parameters of intensity, and turn-on, turn-off the LEDs that are used as light sources with different spectral characteristics.

ACTUAL OR ANTICIPATED OUTCOMES

The anticipated outcomes of the development of our proposed low-cost spectrometry remote lab are:

- Allow the largest possible number of students with remote practical laboratory experiences, which may not have been possible otherwise, due to the costly spectrometry equipment and the limitations for hands-on lab during the pandemic.
- Include as many asynchronous activities as possible for students who are in different geographical locations, so that they can work at their convenience, thus planning their time individually (using a booking system in the web platform).
- Allow the teacher to show demonstration experiments in classes (virtual, face-to-face or mixed), without having to take the equipment to the classroom.
- Force teachers to elaborate laboratory guides in a very didactic way and prepare video tutorials (in nano courses format) for a precise understanding of the task to be carried out by the student, and also to explain the operational procedures to use the remote laboratory.
- Improve the conceptual learning gains thanks to individual and autonomous active learning experimentation [1][2] with the spectrometry remote lab, compared to traditional hands-on labs done in groups of students.
- Allow the deployment of several identical remote laboratories, due to its low-cost and reduce maintenance costs.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

This work shows the potential use of low-cost 3D-printed spectrometry technology to rapidly deploy remote laboratories. Thanks to the communication capabilities of IoT devices, we were able to integrate our spectrometry software with a web application for remote operation, control, real-time visualization and spectral data collection from our low-cost smartphone spectrometer. The resulting remote laboratory allows students to perform asynchronous and autonomous spectrometry activities, and improve their conceptual learning gains. We believe that such a low-cost spectrometry remote laboratory can benefit developing countries and enable the development of MOOC and MOOL type courses.

REFERENCES (OPTIONAL)

[1] Bodegom, E., Jensen, E., & Sokoloff, D. (2019). Adapting RealTime Physics for Distance Learning with the IOLab. The Physics Teacher, Vol. 57 (6)

[2] Sokoloff D.R. (2021) Active Dissemination—Over Three Decades of Faculty Development in Active Learning. In: Jarosievitz B., Sükösd C. (eds) Teaching-Learning Contemporary Physics. Challenges in Physics Education. Springer, Cham.

KEYWORDS

Low-cost, spectrometry remote lab, smartphone spectrometer