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Case study of NI G Web technology application for remote educational laboratory

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***Abstract* – Over the years, numerous web-based remote laboratories have been developed, providing a practical solution for offering hands-on training and education in various scientific fields, especially in online settings. This article outlines the initial design of a LabVIEW-based remote laboratory with a web interface created using a novel technology, National Instruments' (NI) G Web Development Software. In addition, a reservation system was implemented to manage access to the remote laboratory's web interface, allowing access only at specific times.**

I. INTRODUCTION

Remote laboratories [1] have become a popular tool for teaching electronics and other STEM (Science, Technology, Engineering, Math) subjects in recent years [2]. These laboratories allow students to access real laboratory equipment and experiments from any location with an internet connection, providing a more flexible and accessible learning experience. The use of remote laboratories in electronics education has shown promise in improving students' understanding of the subject while providing a more engaging and interactive learning experience [3]. Since the COVID-19 pandemic has posed significant challenges for experimental laboratory classes [4]–[6], the popularity of remote laboratories in education has risen even more [7]–[9].

In recent years, numerous web-based remote laboratories have been developed and implemented in educational settings. These laboratories enable students to conduct measurements and experiments from their homes, without the need for physical attendance at a laboratory.

One e-learning measurement laboratory was developed in [10]. This laboratory offers the opportunity to access remote measurement laboratories and allows students to engage in various didactic activities associated with measurement experiments. The fundamental element of the software architecture is the integration of the Learning Management System with the remotely accessible measurement laboratories, accomplished through web services and a thin client paradigm.

Another remote laboratory for Field Programmable Gate Array (FPGA) experiments was introduced in [11]. The laboratory enables the execution of experiments both through a web interface over the Internet and locally within the classroom. The system has been specifically designed for advanced digital design and signal processing courses, utilizing sophisticated FPGA platforms. By leveraging this system, students gain complete access to laboratory equipment, advanced software licenses, and FPGA platforms remotely, utilizing standard web browsers and a conventional remote desktop interface.

In yet another study [12], a remote laboratory known as ADCWAN (Analog to Digital Converters on Wide Area Network) was introduced as a comprehensive hardware and software platform specifically designed for testing Analog to Digital Converters (ADC). This remote laboratory offers versatility for both educational purposes and scientific experimentation. ADCWAN employs a Moodle server and a custom Java applet to facilitate access to the authentic measurement laboratory. The overarching objective of this proposed remote laboratory is to enable the scientific training of young researchers, facilitate the dissemination of knowledge, and enable the comparison of metrological information. By providing a combination of theoretical resources and practical tools, ADCWAN allows for the characterization of ADC through various experimental tests.

While the previously mentioned remote laboratories have a web interface, it should be noted that their interface must be created for that specific laboratory and equipment. This means that they are not entirely versatile and may not be fully compatible with all laboratory functions. Therefore, it is crucial to develop a flexible web interface that can be adapted to different laboratory setups, providing more versatility for educational purposes.

By using one programming environment for both the web page and communication with laboratory equipment, such as LabVIEW, these obstacles could be overcome. This approach provides the advantage of seamless integration between the web interface and laboratory equipment, making it possible to design a more versatile and functional remote laboratory. A Remote laboratory developed in LabVIEW that features the web interface was already developed by authors in [13] and [14]. However, the previous remote laboratory web interface used an outdated technology that required the use of a large plugin and an Internet Explorer browser that is no longer supported.

To overcome the shortcomings of the previously mentioned systems, we present a remote laboratory system developed in LabVIEW that features a web interface for online access. The novelty of the proposed remote laboratory lies in the development of its web interface utilizing the new technology of NI G Web Development Software. The web interface of the remote laboratory is further enhanced by a reservation system developed by Levente Fekete, a final-year student at the Technical University of Košice. The proposed remote laboratory system allows students to remotely access and control data acquisition (DAQ) devices and conduct experiments using a web browser.

The article is structured as follows: Section II presents the remote laboratory's general design, along with a system block diagram and description of its web interface. Primary conclusions and planned full article extensions regarding the proposed remote laboratory, as well as possible future developments, are outlined in Section III.

II. LABORATORY ARCHITECTURE DESIGN

The remote laboratory consists of three main components. The first component is a LabVIEW program that controls the DAQ card. The second component is a webpage interface developed using G Web development software, which communicates with the LabVIEW program. The third component is a reservation system that manages access to the remote laboratory. In the first subsection of this section, a brief description of the programming environments and DAQ devices utilized in the development of the remote laboratory will be provided. This will be followed by a detailed outline of the remote laboratory's design and a description of its web interface and reservation system.

A. Programming environment and NI DAQ devices

As already mentioned, the remote laboratory was developed using LabVIEW [15] and G Web development software [16], which are established programming environments commonly used in scientific research and engineering. LabVIEW provides a programming language and development environment that enables scientists and engineers to design, control, and test complex systems using graphical programming techniques. In contrast, G Web development software is a novel web application development environment, first introduced in 2021, that allows users to create dynamic web pages and web applications using a graphical interface. The integration of LabVIEW and G Web development software offers researchers and engineers an efficient way to develop and deploy web-based control and monitoring systems. With LabVIEW, users can design the underlying control and monitoring algorithms for their systems. On the other hand, with G Web development software, they can create an intuitive web interface to interact with those systems.

The remote laboratory was designed to be compatible with NI DAQ devices, which offer high accuracy, resolution, fast sampling rates, and flexible connectivity options, making them suitable for a wide range of applications. A major advantage of NI's DAQ devices is their compatibility with LabVIEW. The standardized programming of NI DAQ cards in LabVIEW enables users to easily connect any card to the remote laboratory or upgrade to a newer model, providing greater flexibility and accessibility.

B. Remote laboratory design

The block diagram of the proposed remote laboratory is shown in Fig. 1.

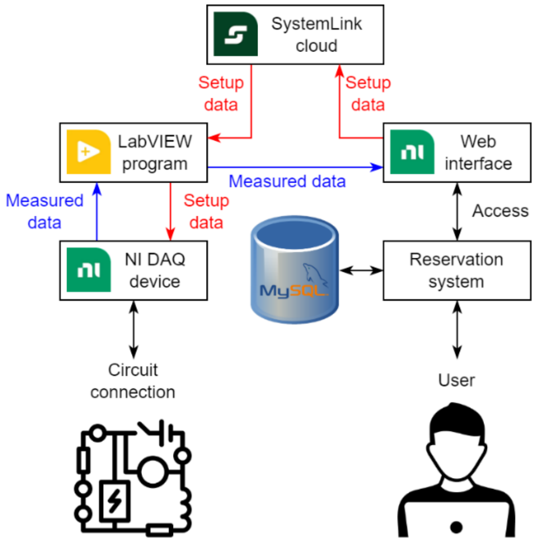

Fig. 1. Block diagram of the remote laboratory design

The remote laboratory's functionality relies on a LabVIEW program which serves as the main control system. The LabVIEW program is used to create signal sample data based on information obtained from the SystemLink [17] cloud. The data includes the amplitude, frequency, number of samples, and waveform shape required to generate the desired signal. The program then generates this signal and sends it to the DAQ card. Additionally, the program reads measured data from the DAQ card and transmits it using HTTP GET. This method is preferred over SystemLink due to its inability to transmit multi-track signal data.

The web interface of the laboratory is shown in Fig. 2.

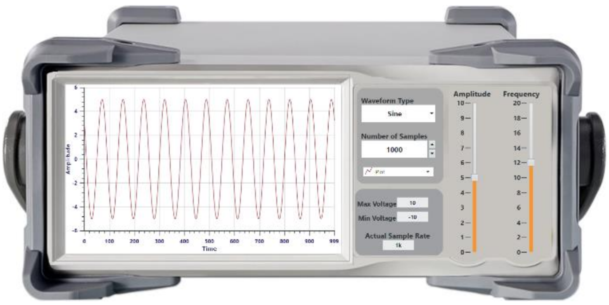

Fig. 2. Web interface of the remote laboratory

The interface consists of two components: a signal setup section and a waveform graph section. The interface is displayed on the screen of an oscilloscope for aesthetic purposes. The creation of the HTML webpage involved the use of the G Web development software. The page allows users to input information about the desired generated signal. This information is then transmitted to the SystemLink cloud for processing. The use of the SystemLink cloud ensures that the transmission of data remains secure, as well as minimizes any potential errors that could arise. Furthermore, the server also loads data from the HTTP GET request that is issued by the main LabVIEW program. This data is used to update the HTML webpage with relevant information regarding the measured signal. Overall, the webpage functionality enables users to modify the generated signal and observe the measured signals in near real-time.

The reservation system of the remote laboratory is implemented in PHP. As shown in Fig. 1 the reservation system is connected to a MySQL database, which contains the login credentials of all users, as well as their reservation times. The reservation system interface includes three pages. The first page is the home page, which allows users to log into the reservation system. The second page displays the available reservation times for the remote laboratory and enables users to make reservations. The third page lists all the reservations made by the logged-in user, including expired reservations. Once a user makes a reservation and opens this page at the scheduled reservation time, the system redirects the user to the web interface of the remote laboratory. Conversely, when the reservation time expires, the user is redirected to the home page of the reservation system.

III. CONCLUSION AND FUTURE WORK

In summary, this paper presented a preliminary design of a LabVIEW-based remote laboratory with a web interface created using the innovative NI G Web Development Software. The study demonstrates that this technology has the potential to create a high-quality web interface for remote laboratories. Also, the implementation of a reservation system has enhanced the functionality and user-friendliness of the proposed remote laboratory. Overall, the proposed remote laboratory has the potential to serve as a valuable teaching tool in experimental electronic classes.

Future work is directed to: (i) implementing the system functionality that enables more than one device to be connected simultaneously, which would enhance the collaborative potential of the remote laboratory, (ii) implementing the ability to export measured data, which would enable students to analyze and manipulate the data outside of the remote laboratory environment, and potentially facilitate more in-depth analysis and experimentation, (iii) developing a more advanced signal setup that includes the ability to import user-defined signals, which would enable students to experiment with custom signal configurations and expand the range of experimental possibilities, and (iv) evaluating the usability and effectiveness of the remote laboratory through surveys, which would enable the collection of feedback from users and facilitate the identification of areas for improvement and refinement.

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