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Cost-Effective Interfaces with Arduino-LabVIEW for an IOT-Based Remote Monitoring Application

Muhammad Asraf Hairuddin, Nur Dalila Khirul Ashar, Amar Faiz Zainal Abidin and Nooritawati Md Tahir

Abstract

To date, research efforts have demonstrated the stimulated need for the Internet of Things (IoT) based monitoring device in their laboratory. The benefits of remote laboratories in overcoming time constraints and the disadvantages of usability of conventional laboratories are well known. In addition to the current control engineering laboratories, a remote lab that incorporates an industry-relevant method has been established to assist in the understanding of data acquisition with cost-effective platform integration. However, one of the greatest challenges is the creation of a low-cost and user-friendly remote laboratory experiment that is ideal for interacting with the actual laboratory via a mobile device. The main objective of this work is therefore to build a remote laboratory system based on the IoT using the LabVIEW-Arduino interface with the example of proportional-integral-derivative (PID) tuning scheme for the LD-Didactic temperature plant. The practical work would include the implementation of the low-cost Arduino module connecting the actual plant to mobile devices. In addition, interfaces have been built using the Blynk application to allow communication between the end user and the laboratory equipment. In line with the Industrial Revolution 4.0 (IR 4.0), the proposed study structure called for the digitization of the current laboratory experiment method.

Keywords: Arduino-LABVIEW, temperature application, remote laboratory, interfacing module, data acquisition, internet-of-things

1. Introduction

Studies in remote laboratory are one form of teaching adaptation that reflects the delivery of practical experience in learning. The common transition from traditional laboratory to remote laboratory has always been associated with automation and online technology, while common implementation involves embedded or monitoring related experiments. As a result, an interactive laboratory can be developed to engage students' comprehension in the learning process. It is worth to shift the laboratory implementation without overlooking the hands-on element. This is in line with the advancement of IR4.0 which extends the education system with IoT into endless possibilities in online learning.

This would support both students and instructors by enhancing the learning environment and exposing students to the industrialized sector. As a core learning process, laboratory experience is essential to learning processes in all areas of engineering. Studies have shown that students who participate in well-designed laboratory experiences gain valuable skills and competencies. Some agree that the development of laboratory activities that enable students to conduct experiments remotely would increase students' commitment to furthering their education. At the same time provide training for high-tech careers by fostering the skills desired by potential employers [1]. Indeed, this not only allow students to actively participate in the learning process, but they will also have vivid experiences, can work in a group or independently, and their attention will improve their commitment and satisfaction [2]. On the management side, remote laboratories benefited by reducing the number of scheduling arrangements, overcoming equipment inadequacy, and reduce overloading students by utilizing the learning versatility provided by IoT.

As a result, the need to transform the traditional laboratory into a remote laboratory is significant. In these circumstances, effective interfaces must be established in order to achieve system monitoring as well as remote application interconnectivity through the internet. Such requirements can be met by using a data acquisition system, in this case LabVIEW (Laboratory Virtual Instrument Engineering Workbench) in conjunction with Arduino board. Furthermore, the proposed system is not limited to laboratory applications and can be extended to other applications such as solar photovoltaic, agriculture, and environmental studies. The importance of such a framework can be seen in open-source hardware as a data acquisition device that is easily configurable to meet the intended requirements of specific applications.

The remaining chapter discusses the trend and review on the open-source interfacing module for remote applications along with implementation challenges in Section 2. Section 3 presents the methodology, to cover overall software and hardware used in this work implementation of interfacing module to acquire the data. The process known as data acquisition will demonstrate how the data transferring process is designed to collect the data from and to the real plant in the laboratory. Section 4 and Section 5 discuss Blynk integration to modular hardware as well with example of case study for PID simulation in real time execution.

2. Related works and research trends

2.1 Trend analysis for remote monitoring

The remote laboratory has been used for the past 20 years and is still used progressively for learning technologies, as shown by the publication pattern depicted in **Figure 1**. A basic bibliometric analysis was performed, to compile and evaluate the information obtained from the SCOPUS database's bibliographic sources. This analysis includes a summary of the most relevant keywords related to monitoring applications, as well as the publications trend and subject area that have been published. Over the last five years, publications with an average of more than 50 articles revealed that research interest was concentrated on these keywords namely monitoring, cost, architecture, e-learning, and higher education, as shown in **Figure 2**. The state of the art has presented the most recent status of remote technology progresses, implementations, and applications through many niche studies. This study offers insight into discovering the most important publications of the year, how interest in such subjects has grown over time, and the most studied topics in the subject area.

Current trends in total publications, as shown in **Table 1**, indicate that this research is expected to receive demand from the engineering and education sectors

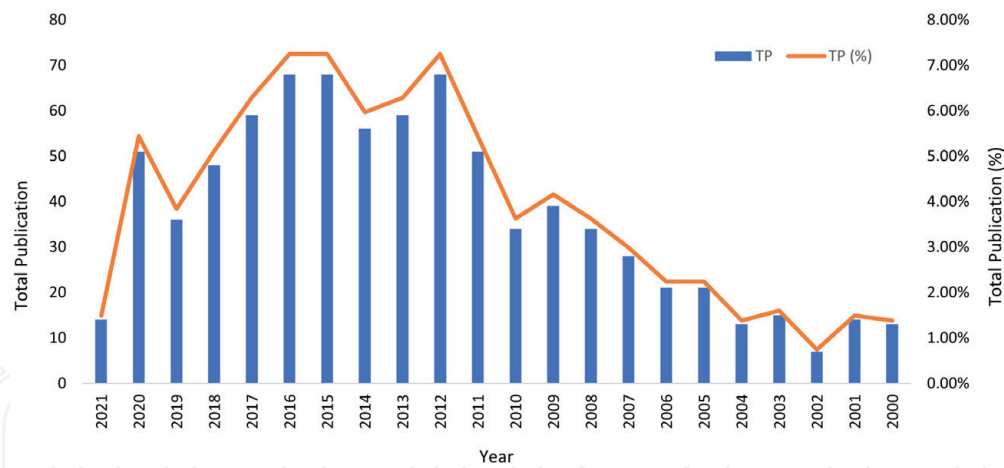


Figure 1.
 Total publications by year.

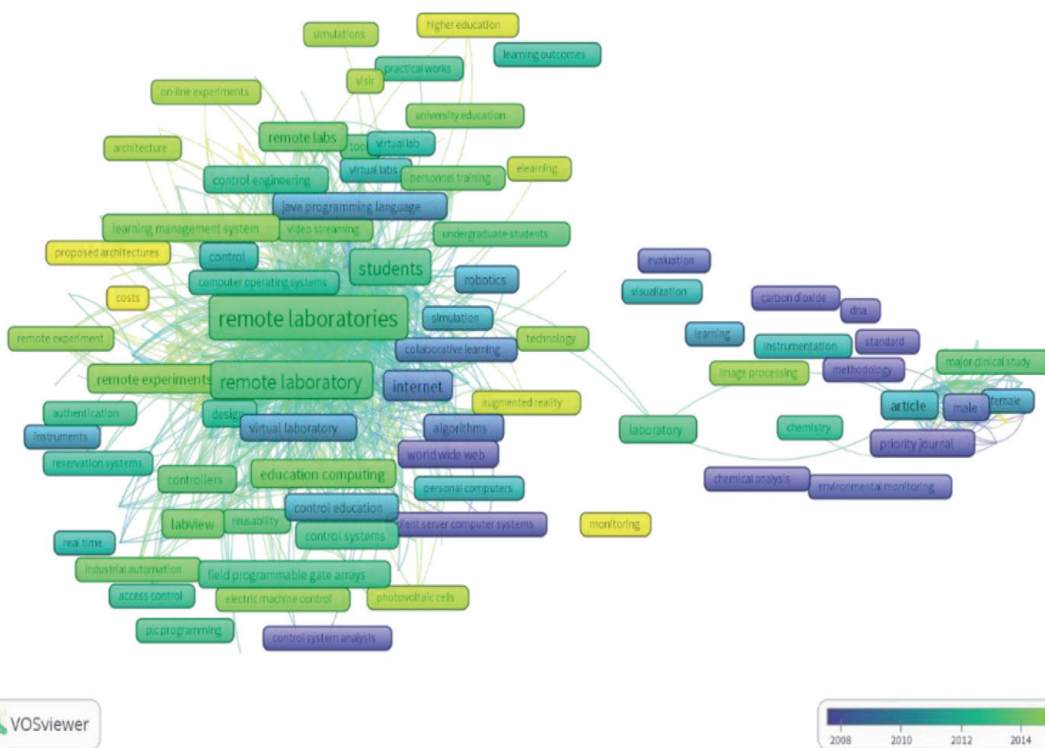


Figure 2.
 Top keywords with VOSViewer visualization map.

to establish remote monitoring. Surprisingly, engineering accounts for 53% of total publications, led by social science, physics and astronomy, and computer science, which each contribute between 27%, 25%, and 22% in the subject field of remote monitoring applications.

2.2 Consideration of LABVIEW in remote laboratory application

LABVIEW offers simple interfaces in form of graphical programming through Graphical User Interface (GUI) instead of text-based programming. The environment development of the project with front panel such as controls (known as input) to supply information to the VI, indicators (known as output) display the results based on the inputs given to the VI and block diagram to comprise of graphical block programming that applies data flow concept is known as virtual instruments (VIs).

Subject Area	TP	%
Engineering	501	53%
Social Sciences	252	27%
Physics and Astronomy	232	25%
Computer Science	203	22%
Chemistry	43	5%
Medicine	39	4%
Mathematics	29	3%
Biochemistry, Genetics and Molecular Biology	28	3%
Agricultural and Biological Sciences	24	3%
Materials Science	23	2%
Environmental Science	19	2%
Earth and Planetary Sciences	17	2%
Energy	17	2%
Business, Management and Accounting	13	1%
Chemical Engineering	12	1%
Psychology	10	1%
Arts and Humanities	9	1%
Immunology and Microbiology	8	1%
Neuroscience	5	1%
Pharmacology, Toxicology and Pharmaceutics	5	1%
Veterinary	5	1%
Multidisciplinary	4	0%
Decision Sciences	3	0%
Dentistry	3	0%
Economics, Econometrics and Finance	3	0%
Health Professions	3	0%

Table 1.
Subject area.

Dataflow programming in LABVIEW executes the flow of data through the nodes on the block diagram in sequence order. The design of VIs will determine the block diagram structure based on function code, in which data flow through the interconnected wires. When all of its inputs are available to execute the function code, it supplies data to its output terminals and passes the output data to the next node in the dataflow direction. Most other text-based programming languages are executed by a block diagram node and adopt a data flow model of programme execution. The execution order of a programme is determined by the sequential order of programme elements in control flow. All the items on the front panel will appear as terminals on the back panel. The virtual Instrument Software Architecture (VISA) is used to interface standard I/O for instrumentation programming. To summarize, **Figure 3** depicts the key components as mentioned above that will be implemented as a remote monitoring system.

Various other studies of remote laboratory applications have been applied, such as in the field of physics [3], electronic sensors [4], vibrating beam [5], and rain gauge [6]. Previous researchers demonstrated various type of innovation in their remote learning. Galan D. et.al [7] have demonstrated the usefulness of conducting remote lab experiment for optical levitation that require proper setup to avoid harmful effect on the skin and eyes. Abreu P. et.al [8] have demonstrated the feasibility of



Figure 3.
General visualization block for software dataflow in remote monitoring.

performing experiments and monitoring pressure parameters of a pneumatic system that comprises of valve and pneumatic cylinder. Moreover, other study on robotics application have also ventured into remote laboratory application. Such application was explored by Angulo I. [9] who successfully replicates actual robotics experiment remotely. Based on these literatures, to the best of author knowledge, similar replication in experimenting a temperature process that simulates industrial lab equipment has yet to be developed. The framework replication can be possibly addressed, nevertheless more study is required by considering factors such as number of parameters, existing equipment and the system integration with IOT platform. The integration of temperature process from the laboratory plant to the user device usually incurs high cost when outsourced to third party. **Table 2** summarizes the interfacing technique and data acquisition system that implemented in the remote monitoring development.

This study mainly targeted on the framework development to integration the Arduino-LABVIEW by presenting proof-of-concept implementation of the IOT system using Blynk application platform. This work proposed the low-cost interfacing module as alternative, and with the available commercial and open software, development could be made relatively easier. Data acquisition with LABVIEW DAQ card have been explored to many applications in remote monitoring. However due to cost issue, another alternative with lower development cost is preferable. Considering Arduino board as cost-effective solution for transforming the system capable to perform remote monitoring, thus elevates value to the use of LABVIEW to remain relevant. Taking example of remote experimentation framework at low-cost development for a temperature process control which can be accessed via student's mobile devices, the interfacing technique to be proposed in this work will benefit other researchers as a reference point to design their own data acquisition system in future.

Among all, the low-cost interfacing module have been studied in either for standalone or remote applications. Several previous works will present the current and latest interfaces used as data acquisition module to integrate between real applications to the LABVIEW. For a simple system, mostly adopted Arduino or Raspberry Pi boards Arduino is the highest among all.

2.3 Challenges and opportunities to real time execution in remote laboratory

Despite the fact that LABVIEW integration with Arduino demonstrated compatibility and minimizing device costs, the challenge in terms of integration process from physical laboratory to remote laboratory remains the most challenging so far, without denying that such project implementation is possible. However, interface integration between systems can be accomplished successfully with less effort if the issue of implementing remote laboratory into functional implementation is understood. The following are examples of such obstacles:

Article title	Application theme	Platform for interfacing hardware			
		Arduino	Raspberry-Pi	NI related-DAQ	PLC
Arduino and LabVIEW in educational remote monitoring applications	Education	•		•	
Remote monitoring and control of VFD fed three phase induction motor with PLC and LabVIEW software		•			•
Remote monitoring of BLDC motor using LabVIEW and zigbee	Healthcare	•			
An efficient IoT based biomedical health monitoring and diagnosing system using myRIO				•	
Development of a Medical Care Terminal for Efficient Monitoring of Bedridden Subjects		•			
Smart multi-level tool for remote patient monitoring based on a wireless sensor network and	Residential	•			
IoT application on establishing smart home		•		•	
Intellisense and remote centralized security monitoring system for the ventilation system in deep mining					•
Design and Real Time Implementation of SmartWater Management using LabVIEW and IoT	Agriculture			•	
An estimated method of visibility for a remote sensing system based on LabVIEW and Arduino	Energy	•			
Solar power remote monitoring and controlling using Arduino, LabVIEW and web browser		•			
Remote air quality monitoring system by using MyRIO-LabVIEW	Environment	•		•	

Table 2. Summary of remote monitoring system using LABVIEW and interfacing hardware.

- **Hardware configuration:** The development the system, take into consideration the hardware that will be used, as this will impact the data flow process. Different setup configurations necessitate different initialization settings, necessitating the creation of a specific algorithm. To minimize errors, electronic components are chosen in such a way that they are configurable and easy to interface with.

- Complexity of data transfer: Transmission and storage become more expensive, while IoT adds complexity to the process of sending a continuous stream of data. These data will eventually affect the storage system.
- Internet connectivity: Since the internet connects the physical laboratory and the Blynk application, the laboratory has been enhanced to include the internet of things functionality. A connection to the internet allows the user to access the laboratory via smartphone or remote processing computer. However, the equipment's reliance on the internet has a downside when access is disrupted, or an internet interruption occurs.

As a result of executing the remote laboratory, the targeted programme can be further extended to support IR4.0 and be compatible with IOT. The use of open-source interfacing device provides advantages in terms of cost effectiveness, usability, and rapid prototyping to adjust the device design accustoms to applications and niche platforms built for particular use cases. This adaptation can increase the opportunities for educational institutions to form collaboration networks.

3. Methodology

To read, monitor, and control sensor data, LabVIEW employs a virtual instrument. MyRIO, DAQ, and NI-ELVIS are examples of known hardware interfaces. This hardware works on the same principle as the interfaces between the actual plant and the LABVIEW programming. Arduino and Raspberry-Pi are two of the most common data acquisition devices that support open-source programming by transforming functional interfaces into low-cost interface hardware. The use of LABVIEW with open-source hardware is gaining popularity due to increased practical implementation, especially in remote monitoring applications. The current study can be used as a pilot guide for developing a remote laboratory that is similar to an industrial-based temperature process. The proposed framework is intended to provide benefits in terms of practicality and cost-effectiveness. The built interface module in the proposed framework will provide access to the laboratory experimental setup, is illustrated in **Figure 4**.

Any experimental parameters or configuration input can be fed into the Arduino platform and transmitted to any user's mobile device connected to the laboratory network. The student can use this to remotely manipulate lab parameters and evaluate the outcomes without having to be physically present in the laboratory. This development's laboratory experiment involves data acquisition and PID control tuning of a modular-based LD-Didactic temperature equipment. A platform for reading and transmitting data and control parameters between the user and the remote laboratory setup is needed to design the module for this experiment (refer **Figures 5 and 6**). In addition, a user interface for displaying output that is accessible via mobile devices is required. Both temperature process modeling and PID controller tuning can be accomplished through algorithm development.

A mechanism for data collection necessitates an array sequence of data collection and transmission. When the thermocouple sensor reads the temperature of the oven, the input temperature transmits the data to the control unit of the processing computer, which is pre-installed with LABVIEW. Furthermore, prior initialization is required to establish LINX interconnectivity with a pre-programmed script of Arduino UNO using ATmega328P microcontroller operating at 16 MHz clock speed, a 32kB Flash memory, a 2kB SRAM, six analogue input, six I/O, one UARTs, one I2C, and one SPI. The gateway processes the received data and posts aggregated data with timestamp to the Blynk cloud. The temperature data are then stored in an 8-bit array and synchronized by sending it to the cloud. The current study can be used as a pilot template for establishing

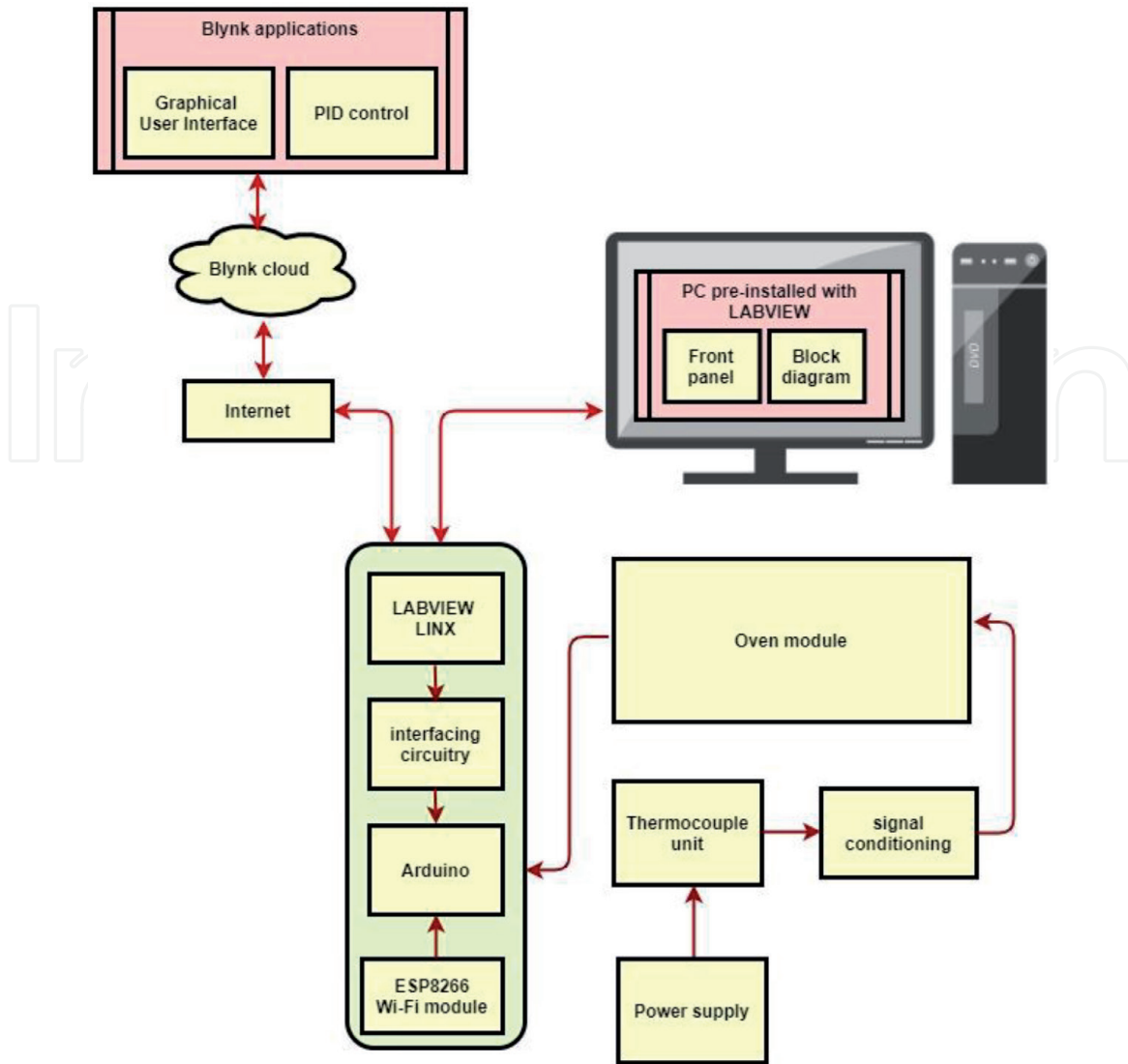


Figure 4. Block diagram for modular based LD didactic temperature monitoring system and control with IOT.

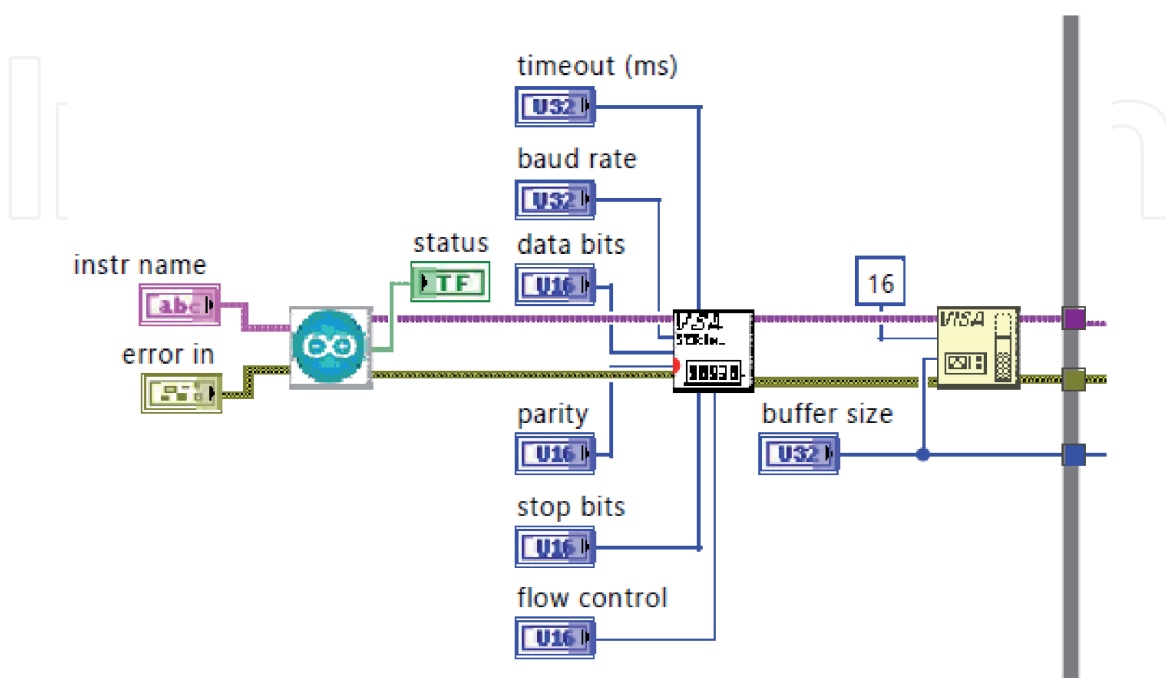


Figure 5. LABVIEW's block diagram interfaces with Arduino module.

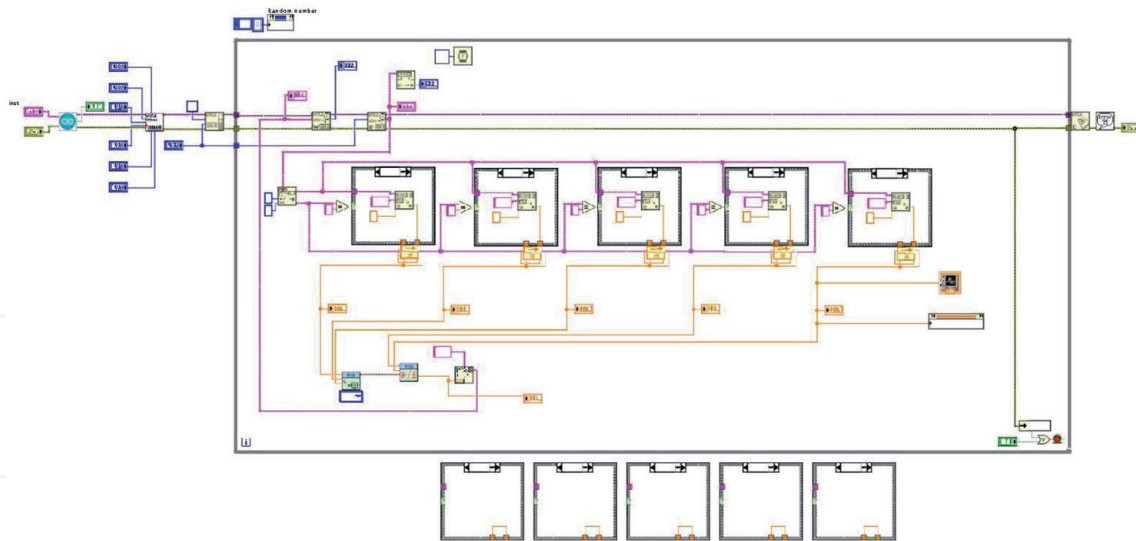


Figure 6.
Full LABVIEW's block diagram to perform interfacing with Arduino and PID control system.

a remote experiment between a temperature control plant and a mobile device to achieve remote laboratory application. The programming sequence is as follows:

Step 1: Initialize pin and load ESP8266 libraries in Arduino IDE.

Step 2: Setting up the network credentials: SSID and Passkey to establish IOT communications.

Step 3: Install NI VISA, VI Package manager

Step 4: Establish connection between Arduino board and LABVIEW. Then search for LabVIEW Interface for Arduino -- Firmware -- LIFA_Base. Conduct port setting and connect the board with LINX Firmware Wizard.

Step 5: Read temperature measurement and transfer to LINX Firmware Wizard.

Step 6: Transfer local data to cloud.

Step 7: Visualize measured data in Blynk application.

4. Blynk integration of IOT module with open-source hardware

Open-source platform for realizing the remote monitoring applications is increased nowadays. To achieve remote capabilities, there is a need to develop a low cost and user-friendly interfacing technique, which is suitable for communicating the physical experimental system and the student's mobile device in real time, realizable through IOT development. Among various options, Blynk application which is available with IOS and Android apps is capable to control the open-source hardware such as Arduino and Raspberry Pi. The interfaces in digital dashboard for IOT interfaces enable centralized data collection and analysis which is beneficial for laboratories applications. Even though there is existing IOT based data acquisition to perform remote monitoring function, however high cost of data acquisition device limits the actual implementation. Therefore, the proposed interfaces using Blynk application are the best economically available to display the temperature receive from this experiment conducted in laboratories.

Online display of data measurements is commonly dedicated for end user which accessible with phone or computer. In this case Blynk due to its simplicity of user interface programming by simply dragging-and-dropping widgets, network cloud can be configured conveniently, and access capability from both smartphone and laptop/computer. The best feature is to exploit the laboratory equipment while deploying the system away from the real experiment setup which can be monitored

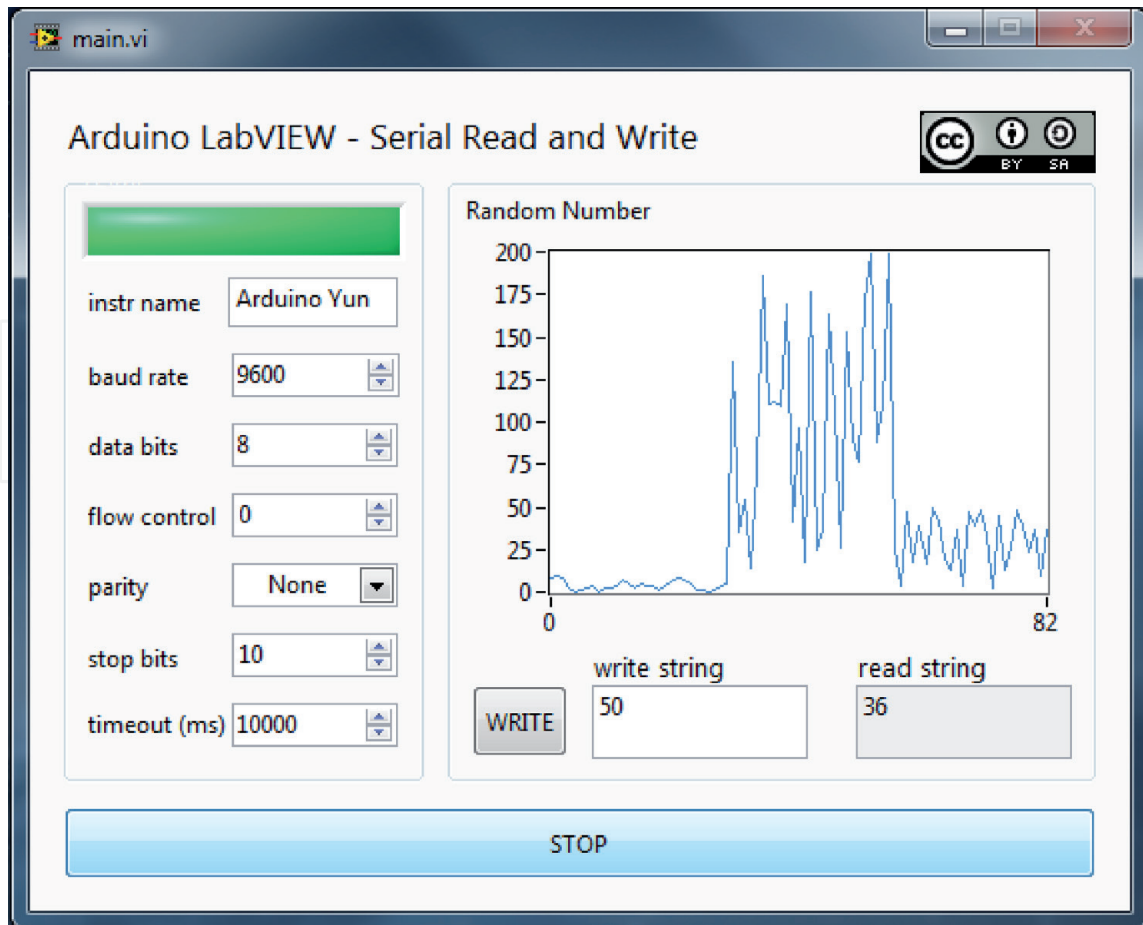


Figure 7.
VIs for Arduino-LABVIEW serial read and write.

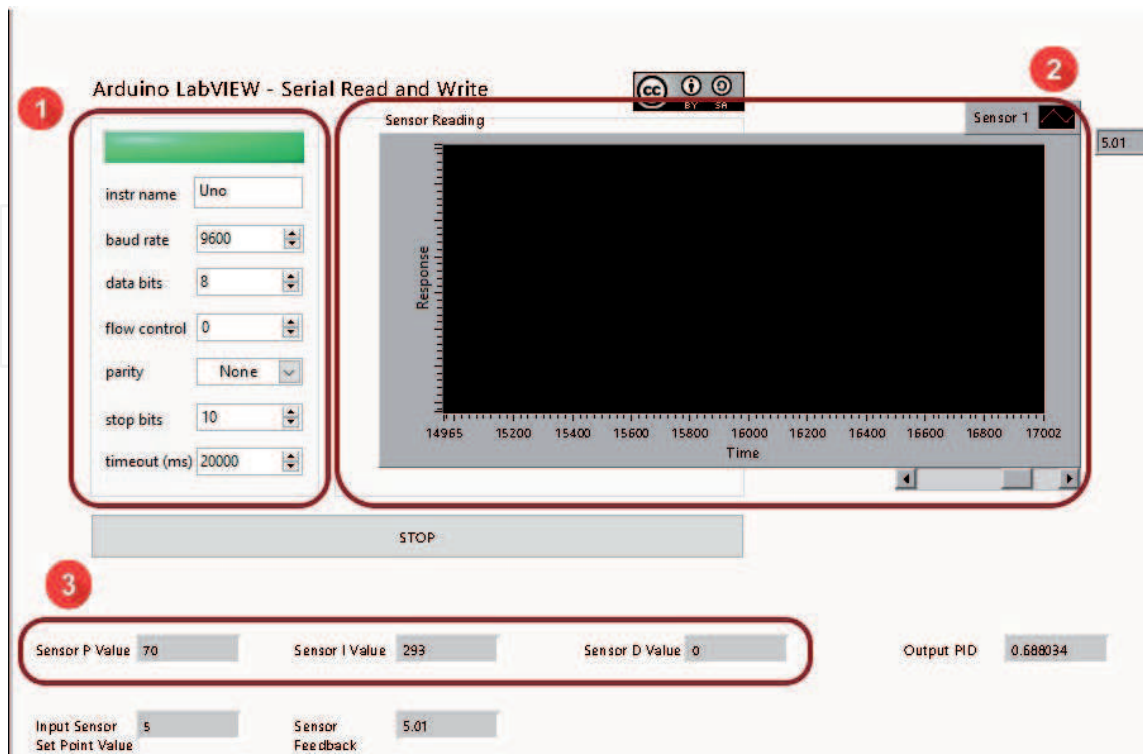


Figure 8.
VIs from the front panel of the PID control and monitoring system (1) Arduino-LABVIEW serial read and write (2) waveform chart (3) PID setting parameters.

and controlled from Blynk dashboard. The developed dashboard helps to provide better monitoring system with continuous monitoring and advanced data analysis which will be conducted later. Data acquisition process using Arduino-LabVIEW and IOT system need to be programmed in Arduino Integrated Development Environment (IDE) in terms of how to manage data sequence and arranging for data transferring process. While data retrieval from either the processing computer or plant to serve as data logging functions is controlled by Blynk, it involves the Blynk interfaces to be remotely monitored away from the experimental setup with internet connectivity. The collected data are made available to remote users in graphical form.

In order to build the data acquisition system with IOT interfaces, Blynk Arduino Library is required to install for establishing the firmware in the Arduino. To start with, BLYNK application requires to be configured and registered using an email. An authentication code with the SSID and the password of the network station is created uniquely for each of developed, and thus need to write these details as part of programming code. As shown in **Figure 7**, the design created for remote monitoring application to apply in temperature experiment study contains four slider widgets to represent the variables used for tuning process and a SuperChart widget to display real-time graph (see **Figure 8**).

5. Real time PID tuning control for LD didactic temperature plant

In addition to the existing control engineering laboratories, integrating an industry-relevant process with a remote lab has increased the understanding of temperature process modeling and tuning scheme. Obtaining accurate temperature control is crucial when simulate the PID tuning parameters namely K (proportional gain), Ti (integral time) and Td (derivative time). **Figure 10** demonstrates the experimental setup of the temperature measurement system. The plant contains several modular types of thermocouple unit, signal conditioning unit, meter, and processing unit to preinstall with LABVIEW. Real-time tests are shown in **Figure 11**, have revealed that the acquired measurement of plant temperature with several PID setting can be observed from the

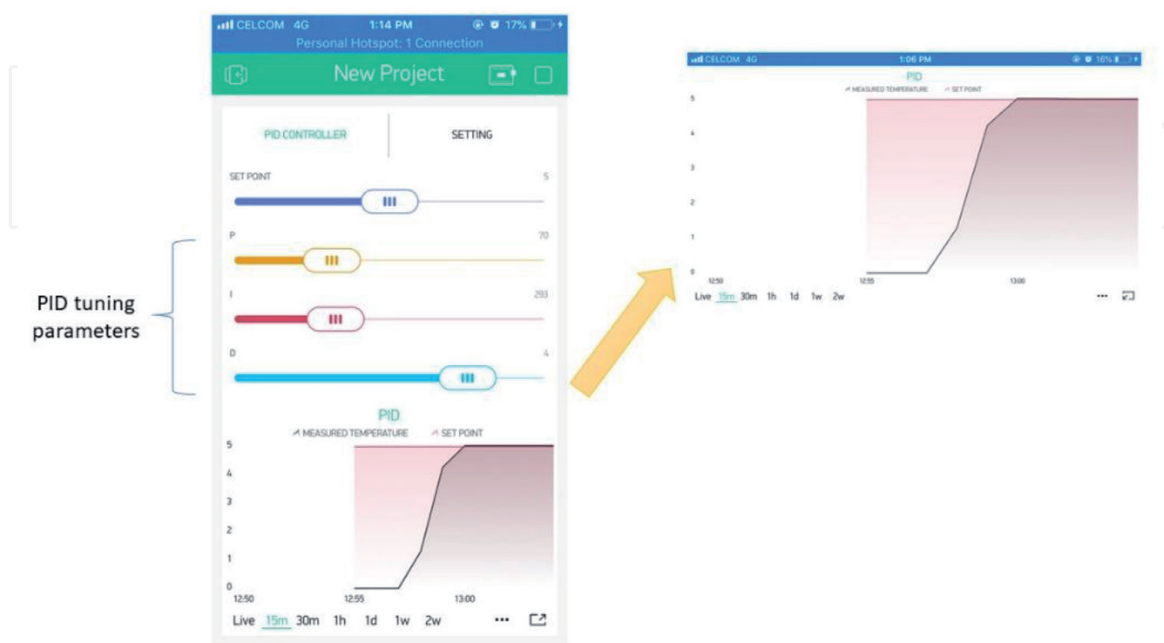


Figure 9.
Blynk interface with widgets configured for remote monitoring.

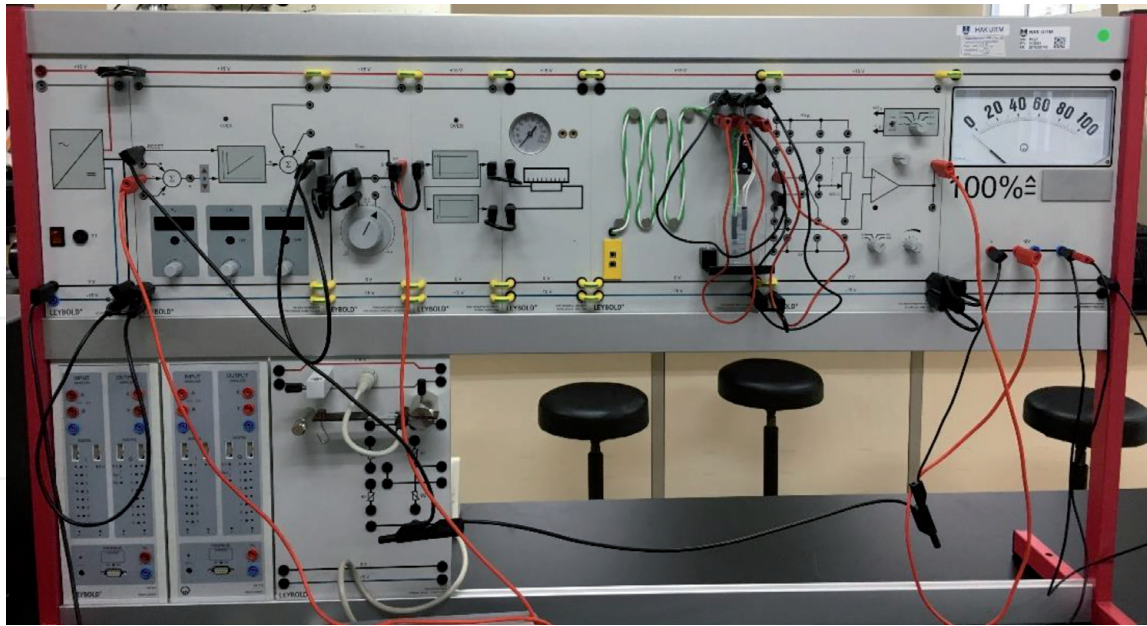


Figure 10.
Experimental setup.

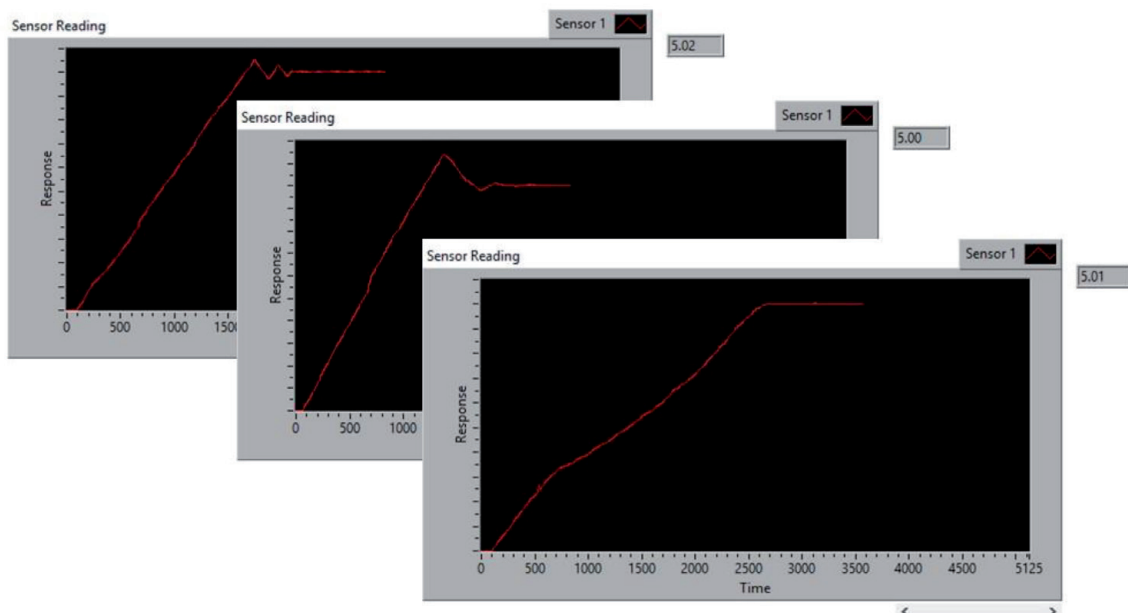


Figure 11.
Simulations results on PID tuning.

produced graph. The result based on the graph which represented from the PID tuning demonstrate the working of Blynk application to transfer and receive temperature data is acceptable and reliable. Moreover, the alert system was designed to alert when our hardware interface disconnects from the Blynk (Figure 9). Thus, IOT interface has made possible with the presence of low-cost module. Additionally, this study will also provide learning experience in creating a framework to digitize an existing process for monitoring purposes.

6. Conclusions

This chapter describes data collection and device integration into IOT applications for remote monitoring. Coordination of data transfer and aggregate technique

is used to ensure the effectiveness of the interfacing technique for realizing the remote laboratory. Using an open-source feature with LINX and Arduino micro-controller board as the gateway of data communicating between plant and mobile device, the advantage and challenge were presented, benefiting the end user in terms of more realistic hands-on and a better understanding of the method. Following up on recent progress, an improved version of the remote monitoring for temperature sensing will be published, along with new models and applications.

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Conflict of interest

The authors declare no conflict of interest.

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References

- [1] M. Hernández-de-Menéndez, A. V. Guevara, and R. Morales-Menendez, "Virtual reality laboratories: a review of experiences," *Int. J. Interact. Des. Manuf.*, vol. 13, no. 3, pp. 947-966, 2019.
- [2] M.-H. Zhang, C.-Y. Su, Y. Li, and Y.-Y. Li, "Factors affecting Chinese university students' intention to continue using virtual and remote labs," *Australas. J. Educ. Technol.*, vol. 36, no. 2, pp. 169-185, 2020.
- [3] C. Arguedas-Matarrita *et al.*, "Remote experimentation in the teaching of physics in Costa Rica: First steps," in *2019 5th Experiment International Conference (exp. at'19)*, 2019, pp. 208-212.
- [4] A. Benhamouda, B. Benmounah, N. Baira, and S. Kahmous, "Design and Implementation of a Low-Cost and Modular Remote Lab Framework: Application to Electronic Sensors," in *International Conference on Interactive Collaborative Learning*, 2017, pp. 657-664.
- [5] A. Cardoso, V. Sousa, M. T. Restivo, and P. Gil, "Demonstration of a remote lab based on a vibrating beam apparatus," in *2016 13th International Conference on Remote Engineering and Virtual Instrumentation (REV)*, 2016, pp. 357-358.
- [6] A. Cardoso, J. Leitão, P. Gil, A. S. Marques, and N. E. Simões, "Using IPython to Demonstrate the Usage of Remote Labs in Engineering Courses—A Case Study Using a Remote Rain Gauge," in *International Conference on Remote Engineering and Virtual Instrumentation*, 2018, pp. 714-720.
- [7] D. Galán *et al.*, "Safe Experimentation in Optical Levitation of Charged Droplets Using Remote Labs," *J. Vis. Exp. JoVE*, no. 143, 2019.
- [8] P. Abreu, J. S. Valiente, L. De La Torre, and M. T. Restivo, "Remote experiments with pneumatic circuit using a double rod cylinder," in *2019 5th Experiment International Conference (exp. at'19)*, 2019, pp. 410-414.
- [9] I. Angulo *et al.*, "RoboBlock: A remote lab for robotics and visual programming," in *2017 4th Experiment@ International Conference (exp. at'17)*, 2017, pp. 109-110.