A LabView Based Online Control Experiments for Students' Learning

Kolapo Alli, *Member, IAENG,* C.Ijeh Ogboi, Daniel Ale, A.O Ajibade, and Folorunso Oladipo

***Abstract*—The buoyancy, dexterity and robustness of internet technologies have given rise to the field of online experimentation. The advantages of placing laboratories online have fuelled the development of this new sphere of laboratory work with a lot of research on-going. While the global set of experiments available on the internet grows, there is a shortage of online introductory experiments in the field of control system engineering. The focus of this study was to expand the set of online experiments in the control engineering field by familiarizing users to control system. In this paper, the development of DC control experiments using i-lab interactive architecture is presented. The study is to design and develop Graphic User Interface (GUIs) using LabVIEW, to ease students in performing position control, speed control and system modeling of the DC servomotor experiments platform. This platform is implemented online using Massachusetts Institute of Technology (M.I.T) interactive laboratory architecture. The scope of this project is to apply virtual instruments to implement the Proportional-Integral-Derivative (PID) controller in position control, speed control and modeling of the control system. PID controller was used to control the output response and stabilize the control system. Interactive software is developed to help the students to visualize and analyze the system.**

***Index Terms*—LabVIEW, iLab, PID Controller.**

I. Introduction

THE field of automation control system and engineering is largely unexplored in the underdeveloped and the developing countries. Few universities undergo course work in control system and engineering and even fewer have labs for servo control system. This is the case despite the fact that the field of automation control system and engineering stands as one of the most promising of the future. Even, the economy of the world depends on servo control [1]. The world is gearing up for the next level of automation where every device would be smart and able to do lots of things on their own without human participation. Typical areas of application of servo control system are found in the manufacturing industry, in scanners, printers, cameras, robots, CD players, vehicles and instrumentation. A characteristic feature of motion control is that, it is often possible to obtain mathematical models of the systems from first principles, possibly with a few complementary experiments. A simple DC motor can be used to illustrate motion control. Typical experiments are to control the speed or the motor angle in desired ways. Examples of control problems are: Stabilization of an unstable system, damping of a swinging load on a crane, motion planning for a moving robot, traction control of cars [12]. This research work, reported here, was prompted by the limited number of online lab experiments and lectures in the field of control system and engineering. The focus of this study was to expand the set of online experiments in the control engineering field by introducing newbies to control system. Hence, the availability of online experiment setups and laboratories can go a long way in facilitating the development of any technological system and hence, country or region. The set of online experiments which this research work put up are based on a servomechanism control system implementing PID controller. Three experiments have been set up at the Obafemi Awolowo University by this research effort. The experiments are:

1) The position control experiment
2) The speed control experiment
3) The system modeling experiment

II. Review

Previous works have been done on development of real-time online control laboratories and virtual instrumentation. These researches that are relevant to this project are discussed next to demonstrate continuity from previous researches: Below is an account of some of the existing online control engineering laboratories. At the University of Western Australia (UWA), a telerobot laboratory has been set up using an ABB robot. The telerobot laboratory enables students to practise kinematics [25]. The user is required to download and install a client application before the experiment can be run. The client application was developed in LabVIEW. The client application submits the user's typed in credentials to the remote laboratory for authentication and then is used to send in data for the control of the telerobot. For the experiments, students are required to compute the kinematics of the telerobot and, based on their computations, instruct the telerobot to pick and place items on a chequered surface. The laboratory may be found at http://telerobot.mech.uwa.edu.au/. [17] described a recently developed DC motor position control experimental setup that can be accessed via the Internet. The experiment consists of two primary elements i.e a server and a client computer communicating with each other. A server consisting of a low-cost microcontroller, Parallax's 40-pin Basic Stamp 2 (BS2P40), interfaced with an embedded ethernet IC, Cirrus Logic's Crystal CS8900A, and the client computer sends/receives data to/from the microcontroller using User Datagram Protocol (UDP) packets. The client computer

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K.S. Alli is a Ph.D Student at the Department of Electronic and Electrical Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria. Email: allikolapo@gmail.com
C.Ijeh-.Ogboi is with the Department of Electronic and Electrical Engineering, Afe Babalola University, Ado-Ekiti, Nigeria. Email: chrislab2008@gmail.com
D.T. Ale is with the Department of Electronic and Electrical Engineering, Afe Babalola University, Ado-Ekiti, Nigeria. Email: aledt@abuad.edu.ng
A.O. Ajibade is with the Department of Electronic and Electrical Engineering, Afe Babalola University, Ado-Ekiti, Nigeria. Email: aded1d1@aol.co.uk
Oladipo is with the Department of Electronic and Electrical Engineering, Afe Babalola University, Ado-Ekiti, Nigeria. Email: oladfol2013@gmail.com

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connects to the server using Java applets that allow the user to command the position of the motor via a graphical user interface. [1] developed a robust ilab platform for conducting robotic arm experiments. Three experiments were designed on the robotic arm platform: position control experiment, an experiment on the effect of gravity on the control of the robotic arm and a trajectory planning experiment. The experiments were designed using LabVIEW programming. This platform was implemented online using Massachusetts Institute of Technology (M.I.T) interactive ilab architecture. The existing batched ilab architecture of Obafemi Awolowo University, Ile-Ife, Nigeria was also upgraded to support the interactive architecture and provide visual feedback to the users. The major weakness about this work was that there was error of non linearity in the motor movement of the robotic arm in response to the linear input. This problem could actually be solved by implementing PID controller to the robotic arm system which would give the users control over the torques of the individual motors.

At the Department of Electrical and Computer Engineering, National University of Singapore, A Web-Based Remote Laboratory Experimentation was developed by [19], which enables electrical engineering students to control the real instrument through the internet and conduct oscilloscope experimentation remotely which manipulate the real instruments through virtual instruments interface developed by 3D modeling.

The exploitation of live video reduces the complexity of 3D modeling as well as promises a higher visual quality scene. The software and hardware structure of this video system was introduced.

At the University of Siena, an “Automatic Control Telelab (ACT)” was developed by [7]. In this laboratory, the laboratory user is required to design a PID controller for the experiment he wishes to perform. The design is done using MathWorks’s Simulink. Before carrying out the experiment, the user uploads his designed controller to the laboratory.

An online laboratory has been developed at the School of Engineering, Swiss Federal Institute of Technology (EPFL) by [23]. The laboratory is called the eMersion Remote laboratory or the eMersion project. Experiments deployed in this laboratory in the field of automatic control include an inverted pendulum experiment and a servo drive experiment. The third experiment deployed is a thermal process training experiment. The eMersion project calls the client application used for its experiments the Cockpit. The Cockpit comprises an experimentation component a java applet which serves as the experiment engine, a SysQuake remote component a php application which students communicate with, to provide their experiment specifications and receive experiment results, and an eJournal i.e “an electronic version of the traditional laboratory journal or laboratory notebook”.

An online Metrology laboratories have been developed by [9] to introduce Metrology educators to the use and adoption of Java-applets for students’ learning. These methods have been effectively used as a laboratory course which contributes more to concepts of the conventional lectures in Metrology course at College of Engineering, Albaha University, KSA. The package enhances undergoing incorporation Web-based technologies (Internet home page, HTML, Java programming etc). The use of the Web-based education and training has been successfully tested in class of the undergraduate preliminary year engineering course and students’ positive experience was reported with its use. A study have been conducted by [8] for analyzing the performances of the computer engineering students at Baskent University, Ankara, Turkey on the Lab Sessions of Computer Network Course, in both theoretical and practical means. Students’ assessment were carried out weekly from the lab sessions throughout the academic semesters of 2007-2008, 2008-2009 and 2009-2010 by the use of One-way and Two-way Anova and Chi-Square tests were examined. Furthermore, questionnaires were administered to students to state their opinions about the course while lab sessions were assessed at the end of each semester during 3 years. A web-based laboratory for control engineering was developed at the University of Bologna by [6]

A. THE ARCHITECTURE OF THE LAB

The Three-Tiered iLab Architecture:

The laboratory which has been developed and reported in this paper was developed using the three-tiered architecture developed by the Massachusetts Institute of Technology (MIT) iLab research team. A second architecture, there is a lab server and a client (forming the two tiers). This is shown in Fig. 1. In the three-tiered architecture however, a third tier is included between the lab server and the client. This third tier is called the Service Broker. In the two-tiered architecture, all authentications, user arbitration, database management and control of the laboratory equipment are handled by the laboratory server. In the three-tiered architecture however, the laboratory server is left solely with the responsibility of controlling the laboratory equipment. Hence, the lab server parses user requests (i.e. experiment specifications which the user sends in to the lab), executes requests which are deemed okay and returns the results of the experiment. The Service Broker takes on the function of authenticating users, arbitrating the use of the laboratories and providing access to store results from previous lab sessions. For instance, a user classified as a student may be given access to one type of experiments only. Another person classified as an instructor may have access to the same experiment and also stored data from lab sessions of the students [14]. Fig. 2 shows the three-tiered architecture

The Quanser DC Motor Trainer lab uses the ilab Interactive Architecture. In the interactive architecture, this service is handled by what is called the Laboratory-side Scheduling Server (LSS). When the laboratory owner has specified the periods of the day during which the laboratory would be available to a user system, the need for a second service surfaces.

There is the need for another web service which specifies how long each user can spend in the laboratory performing experiments. In the interactive architecture, this service is called the User-side Scheduling Server (USS). This server defines the size of each time block which a user can be allocated and the maximum number of time blocks which a particular user can reserve for a particular experiment. This server also, having a database, stores the user reservations so that when the particular user logs on to the ISB, the ISB can contact the USS to find out if he has any reservations for the

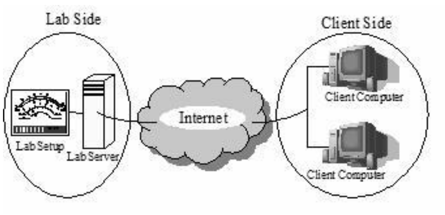

Fig. 1. The Two-Tiered Architecture

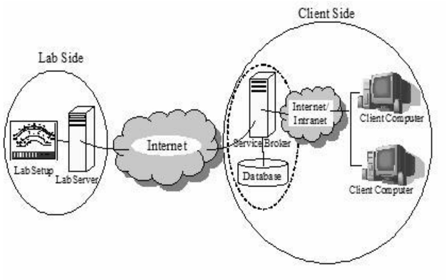

Fig. 2. The Three-Tiered Architecture

particular experiment which he is requesting permission to run. A third service is called the Experiment Storage Server (ESS).

The ESS is responsible for, as its name implies, storing results of each laboratory session for retrieval by users with appropriate permissions.

Two main advantages to the three-tiered architecture are the flexibility it gives to the design of the online laboratory system and the reduction of the burden for the laboratory designer. Hence, each of these additional three services or three servers described, though they could have been coupled into the ISB and ILS, they are decoupled as individual servers with individual databases, with the ISB serving as the central processing unit, authentication and verification system, and router for data. Having two separate scheduling servers, one on the laboratory side and the other on the clients side gives more flexibility to the system [15]. The geographical location of these servers in the Interactive Architecture is flexible.

III. METHODOLOGY

A DC Motor control experiment platform was set up which consists of Quanser DC Motor mounted on the National Instruments Educational Laboratory Virtual Instruments (NI ELVIS II) unit with an inbuilt Data Acquisition Device and connected to power supply. This experiment platform was connected to the PC with LabVIEW Runtime via a USB cable. In this research, three DC motor control experiments were designed which involved the implementation of virtual instruments to produce digital controllers with Graphical User Interface using LabVIEW software. Configuration was also done by installing NI-ELVIS II suite software on the PC which allows user to communicate and monitor the system performance by varying different control parameters. This experiment platform was implemented online using Massachusetts Institute Technology (MIT) interactive architecture. The MIT iLab interactive service broker was installed and configured alongside with an experiment storage server, a user-side scheduling, a lab-side scheduling server and an interactive lab server. Questionaires were administered to the users to carry out evaluation on the systems performance. Figure 3 depicted below shows the QNET Board Slides with NI ELVIS II. The NI ELVIS II has its own DAQ device that connects the PC via USB. LabVIEW was used to implement user interfaces which allows user to take commands the over the DC Motor [27]. The development of position control and speed control experiments are based on the transfer function from the block diagrams depicted in Fig. 4 and 5 respectively.

A. Speed Control System Experiment

The design of the speed control system experiment is based on the block diagram of the closed-loop system illustrated in Fig. 5 whereby the DC motor is controlled using a proportional-integral control system. The speed-voltage transfer function of the DC motor is derived as follows [27]:

$$u = K_p(b_{sp}r - y) + \frac{k_i(r-y)}{s} \quad (1)$$

where K_p represents the proportional gain, K_i represents integral gain and b_{sp} is the set-point weight. The closed loop transfer function from the speed reference, r, to the angular motor speed output, ω_m using Mason's formular is

$$G_{\omega,r}(s) = \frac{(b_{sp}k_p + \frac{k_i}{s})\frac{K}{\tau s+1}}{1-(-k_p(\frac{K}{\tau s+1}) - \frac{k_i}{s}(\frac{K}{\tau s+1}))} \quad (2)$$

The standard desired Closed-loop Characteristic polynomial is

$$s^2 + 2\zeta\omega_o s + \omega_o^2 \quad (3)$$

where ω_o is the undamped closed-loop frequency and ζ is the damping ratio.

$$k_p = \frac{-1 + 2\zeta\omega_0\tau}{K} \quad (4)$$

and

$$k_i = \frac{\omega_o^2\tau}{K} \quad (5)$$

Large value of ω_o give large value of controller gain. The damping ratio, ζ and the set-point weight parameter, b_{sp}, can be used to adjust the speed and overshoot of the response to reference values.

B. Objectives of the speed control experiment

1) To monitor the speed control of the DC servomechanism control system by applying different control inputs.
2) To control the speed of the motor shaft using a proportional-integral (PI) controller.

C. Objectives of the closed-loop position control system experiment.

1) To analyze the impact of Proportional-Integral-Derivative (PID) controller on the position control of the DC servo control system.
2) To lower the effects of the steady-state error (e_{ss}), settling time (T_p) and steady-state time (t_{ss}) of the DC motor control system.

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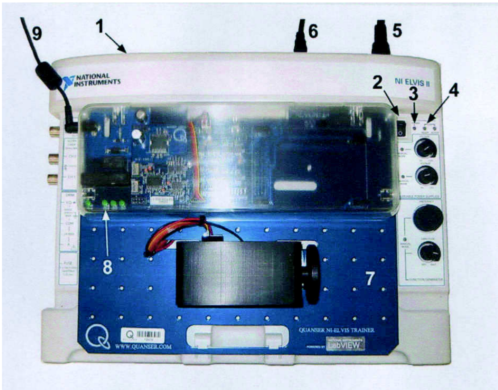

Fig. 3. QNET Board Slides with NI ELVIS II

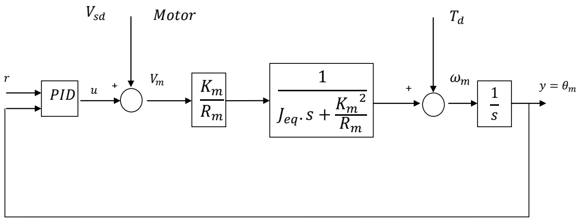

Fig. 4. General Block Diagram for Closed Loop Position Control System

D. Objective of the system modeling experiment.

1) To determine the transfer function of the DC servo control system after specifying the system's parameters.

E. LABVIEW

LabVIEW is originally developed by National Instruments (NI) which is a virtual instrumentation software. It has programming environment which are written graphically using the G language. It makes use of icons instead of lines of text to create applications. The programs implementation involved dragging of blocks onto a front panel or a block diagram and connecting the various blocks together in the block diagram. Each program written in LabVIEW has to do with a Virtual Instrument (VI). The data flows in the block diagram of each developed VI decides the execution of the program (of the VI). Creation of VIs by LabVIEW application are used in test and measurement, data acquisition (DAQ), instrument control, data-logging, measurement analysis and report generation. A Front Panel and a Block Diagram are contained in Each VI. The Front Panel serves as the client's interface. The Block Diagram involves the graphical representation of functions which control the flow of data and objects from the Front Panel [1].

LabVIEW has a feature called Remote Panels and it makes this together with the LabVIEW web server to make it available and control a LabVIEW (VI) over the internet. For a user wishes to access and control the VI would only need to install LabVIEW Runtime engine on his computer. LabVIEW was used to create the lab client. The creation of LabVIEW is a graphical programming environment, and therefore, the LabVIEW VI's Front Panel developed serves as the client's interface through which the client interacts with and the Block Diagram of the VI is responsible for the experiment engine which parses and executes user input.

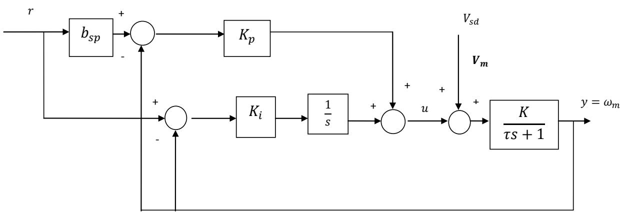

Fig. 5. Speed Control Block Diagram

F. THE CLIENTS

The front panels of the experiment engines created served as the laboratory clients on the user's end. The Remote Panels feature of LabVIEW enables VIs to be embedded in web pages. The front panels of the experiment engines was embedded in WebPages which the user accesses remotely and interactions of the user with these embedded VIs were received and worked on directly by the block diagram of the VI on the laboratory side. Figure 6 and 7 show the Front Panel and the Remote Panel of the Position Control Experiment respectively.

IV. USERS EXPERIENCE

About 120 students responded to the questionnaire, 80% of the students used the system while 20% of the students managed to operate the remote lab within their specified reservation times.

The assessment presented here are based on feedback from the twenty-five students who successfully performed the experiments

1) Laboratory effectiveness: The average score given by the users for the effectiveness of the laboratory (i.e. the experiment clients and the available documentation) was 70%.
2) Level of understanding: From the questions asked the students sequel to their performing the experiments, the average assessment of the depth of their understanding of the concepts being taught, introduced and experimented in the laboratory was seventy-five percent.
3) Users Rating of the Laboratory: The average user rating was 70%.

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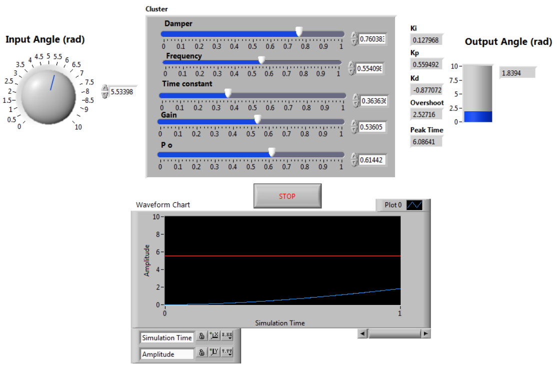

Fig. 6. The Front Panel of the Position Control Experiment

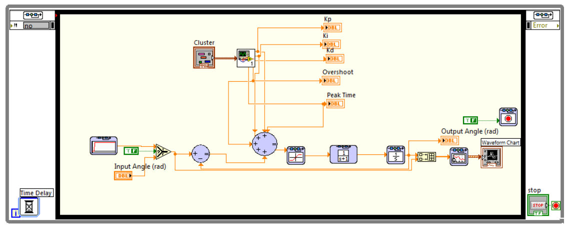

Fig. 7. The Remote Panel of the Position Control Experiment

A. THE RESULTS OF THE LABORATORY EXPERIMENTS

The laboratory has three experiments which are performed on a servo control system. The three experiments are a position control experiment, speed control experiment and system modeling experiment. From the experimental results, it was observed that a proportional controller K_p reduced the effect of rise time and steady-state error. A derivative control K_d have the effect of increasing the stability of the system, reduced the overshoot and improved the transient response while, an integral control K_i have the effect of eliminating the steady-state error, reduced rise-time but increased settling time. Fig. 8 and 9 show the effect of the K_i on e_{ss} of the Motor Speed and the effect of K_d on % Overshoot (PO) of the Motor Position respectively.

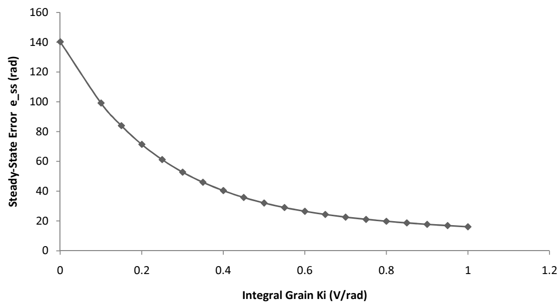

Fig. 8. Output Result of Increase in K_i on Steady-State Error e_{ss} of the Motor Speed using Square Wave Signal

B. THE LABVIEW RUNTIME INSTALLATION

About 30% of students complained that they did not have access to a computer which was connected to the internet on which they could install the LabVIEW Runtime to perform the experiments. The other 70% of the students installed the LabVIEW Runtime, zero percent downloaded the LabVIEW Runtime from the laboratory server. Two students copied the Runtime from us and others got it from them. To ease the LabVIEW Runtime download problem, a copy of the Runtime was placed on OAU's intranet so that students from OAU could download it at up to 8 MB/s and hence download the Runtime in seconds. The slim installation supports the features necessary for Remote Panels. Using this version would ameliorate the download problems, but not solve it as 28.7 MB is still large for low bandwidth networks.

V. CONCLUSION

An online laboratory has been set up at the Obafemi Awolowo University, available at http://ilab.oauife.edu.ng/sb. The position control experiment introduces newbies to the workings of a servo control system. The effect of PID controller to reduce the overshoot, steady-state error and settling time were investigated. The speed control experiment allows students to observe the effect of PI controller to reduce steady-state error on the speed of DC motor. The system modeling experiment is a medium whereby users specified some set of system parameters to some test input to model the DC motor. Hence, work lies ahead on ways of minimizing the laboratory's bandwidth requirements while still presenting the necessary visual, auditory and possibly haptic feedback to the user [4] and minimizing simulations which could give students the feel of being in a virtual laboratory instead of an online laboratory. Experience gained from the setting up of this laboratory showed that the overall development time to deploy a new laboratory could be drastically reduced if LabVIEW is used for the development of the experiment

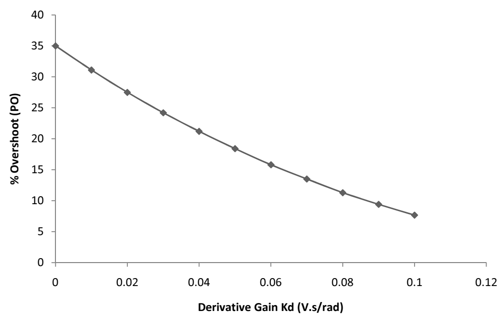

Fig. 9. Output Result of Increasing Derivative Gain K_d on % Overshoot (PO) of the Motor Position

engines and the clients. One reason for this is that one does not need to develop separate applications for the client application and the experiment engine. Secondly, in creating a LabVIEW application, one automatically creates a GUI for it hence; there is no need for creation of a GUI for the client application. The laboratory design was made to be robust so that it is safe for use without human supervision.

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