

Design and Implementation of Web based Remote Laboratory for Engineering Education

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ABSTRACT

Unified approach for improving the technical education is presented in this paper. This includes several individual and collaborative works in various engineering disciplines. The aim of this work is to enrich the learning experience through experimental learning of science and technology in a virtual learning environment on preferred location at any time. The remote laboratory was designed and published in internet. The authorized students can log into the laboratory using the internet connection and use the experimental setup in the allotted time slot. The paper covers, the advancement in e-learning, need for virtualizing the laboratory and the technology for realizing the remote lab. Five different experiments were designed, virtualized and published for remote control. The survey was conducted among the graduate and undergraduate students registered for the online experiments and the feedback graph is plotted. The feedback from the students was positive and that emphasizes the need for a full-fledged remote lab containing experiments from all engineering disciplines and inclusion of this platform in the engineering curricula.

Keywords: *remote laboratory; remote trigger; virtual lab.*

1. INTRODUCTION

More and more scientific disciplines have been switching from vitro to in silico, where the natural phenomenon is explored using the computer simulation algorithms. The Remote triggered virtual labs thus evolved as the powerful tool in this regard of experimentation. It is envisaged that the Remote triggered Virtual Labs are the future scope for learning.

Laboratory classes play a crucial role in engineering schools. Good pedagogical reasons, such as illustrating and validating analytical concepts, introducing students to professional practice and to the uncertainties involved in no ideal situations, developing skills with instrumentation, and developing social and teamwork skills in a technical environment motivate the need for their inclusion in the curriculum. On the other hand, laboratory management can be resource-intensive and expensive, since it requires qualified staff and continuous equipment maintenance and evolution, so that the number of laboratories is often limited. For these reasons, the adoption of alternative access modes is more and more considered by universities. More over the students end up as a spectator because of being in a large group in the traditional laboratory.

Some of the advantages of Remote Triggered Virtual labs are:

- Cost effectiveness - the ability to simulate high cost experiments, which are often complicated and

complex. Virtual labs can greatly reduce the cost of initial purchase of equipment and materials.

- Safety - the elimination of risk associated with running high-powered equipment in electrical labs.
- Flexibility - the provision of a constant lab environment allows students to work on projects and experiments on demand. For courses at a distance, this means that the lab work required for an online engineering course is not only available to the students anywhere, but also anytime as part of the asynchronous tools that student can access for their courses.
- Feasibility - virtual labs support the growing emphasis on distance education by making activities available that were previously found only in traditional courses.

2. ADVANCED REMOTE LABORATORY SYSTEM

Remote laboratory is realized using LabVIEW and NI hardware were used for data acquisition. LabVIEW stands for Laboratory Virtual Instrumentation Engineering Workbench, and the LabVIEW code is referred to as Virtual Instruments (VI) [1]. NI's LabVIEW is one of the most widely used integrated development environments for instrumentation, control and digital signal processing development [2]. The remote labs are also called virtual labs. The main idea behind the remote lab is to access and control the lab from a distant place using suitable

communication method. The user at a distant place conducts the experimental and controls the required parameters. The live streaming video was given for the experiments for controlling the real physical set up. The simulation experiments were provided with the necessary control and visualizations. The structure of the lab is as shown in the Figure 1.

The experimental setups are connected to the servers. The servers will monitor the progress of the experiments. The user at the other end having a Graphical User Interface (GUI) control the laboratory setups by changing different parameters allowed by the virtual lab architect. The lab architecture is having two servers. The master server monitors all critical parameters in the experiments. Also the most important parameter read by the master by dedicated transducers. Any abnormalities in the experiment treated as exception and the master takes over the control of the experiment. This is the exception handling in the remote laboratory. The exception handling is very important in the virtual lab since the control given to the client outside the lab. The user may make unintentional or intentional mistakes and this may affect the normal flow of experiments or may even damage the whole lab. All the security and hardware failure issues should be considered while designing the remote labs. The 'safe go home' algorithm executed to take the experiment to the normal condition if some exception occurred. Then the control was given back to the client if the experiment was under control.

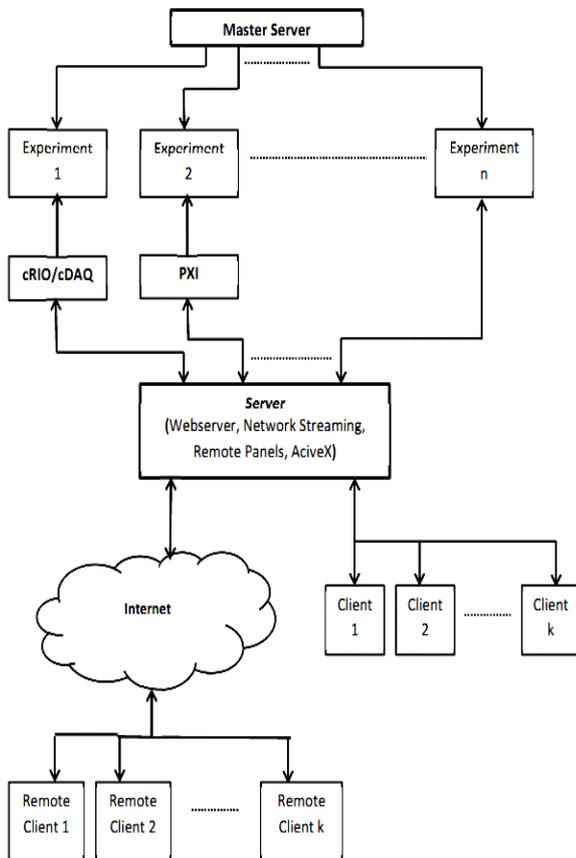


Figure 1. Advanced structure of remote lab

The server will take care of the data traffic and the connection to the clients. The clients may be from the same campus or at a distant location. The local clients connect through LAN since this gives the better data transfer and the streaming. More over the most if the colleges are having the wired LAN which is reliable. The remote clients access the experiment from the system connected to the internet through a web browser.

For the remote control of the experiments with LabVIEW there is a variety of methods. The major Web methods supported by LabVIEW include:

- Remote Panels using LabVIEW Built-in Web Server
- CGI Server technology
- Web Service with Adobe flash
- Web Service with the UI Builder

2.1 Remote Panels

This is the simplest method of interfacing a LabVIEW application with the World Wide Web [3]. In this method, panel images of the application can be constantly broadcast to users through the web at relatively short time intervals. This method is simple since the full VI (Virtual Instrument) front panels are broadcasted, configuration of the LabVIEW built-in Web Server is very simple and straightforward. However, a main disadvantage is that the user cannot interact with the VI. Also, a relatively notable slowdown in the execution of application may occur if a large number of users co-currently access the application.

2.2 Web Services

It enables the invocation of a method on a remote target using standard Web-based protocols. A client sends a request to a remote server, which processes the request and replies with a response, which is then interpreted and displayed by the client application. This communication method is used for all the internet activities such as browsing the Web, checking e-mails, and even reading this article online [4].

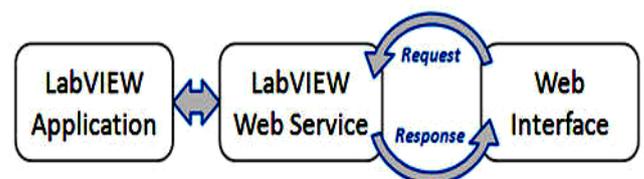


Figure 2. Communication through the web interface [5]

Web services can act as a web application programming interface (API) to any type of software, whether that software is controlling complex instrumentation or simply a database store. To use a web service, a client sends a request to the remote system hosting the service, which

then processes the request and sends back a response (typically an XML). The client can choose to display the raw XML data, but it is more common to parse the data and display it to the user as part of a graphical user interface (GUI) as shown below in Figure 3. LabVIEW Web UI Builder is a standalone, web-based editor that enables LabVIEW users to apply their existing knowledge of graphical programming to create lightweight, web-based applications that are accessible via a web browser [6].

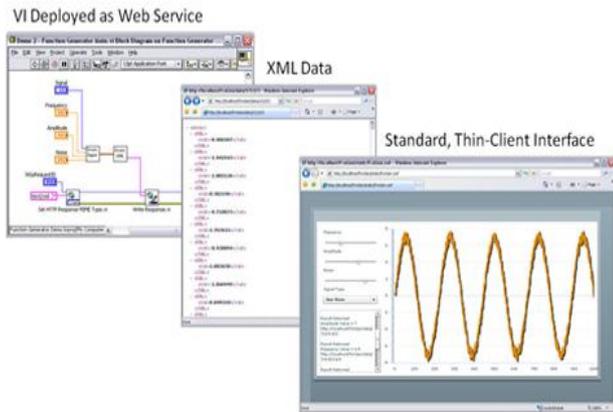


Figure 3. Web services with the user interface [6]

3. DESIGN OF EXPERIMENTS (CASE STUDIES)

3.1 Setup 1: Smartphone Motion Sensor Controlled Wireless Mobile Robot

In this experiment the motion control of a mobile vehicle is done using sensor data from the high end mobile phones. LabVIEW running on a system communicates with the mobile phone using Bluetooth. For sensor integration in system tri-axial accelerometer of mobile phone with android platform is used. An application was made on the android platform for sending the sensor information from the mobile to the computer. The accelerometer sensor data was read by the application installed in the phone and sent to the 'G' program in LabVIEW. The terrain vehicle was connected to the system through Wi-Fi. The vehicle has four driving wheels and the angular velocities of the wheels on each side were independently controlled. Motion control of terrain vehicle is very important research field today. The application of this type of vehicle is in military missions and for reconnaissance.

NI (National Instruments) Wi-Fi DAQ device is a combination of an NI WLS-9163 wireless carrier and an NI C Series measurement module. The WLS-9163 provides both IEEE 802.11b/g and Ethernet connectivity back to a host PC. NI C Series modules deliver direct sensor connections and built-in signal conditioning for a variety of measurements. NI WLS-9163 with 9472 was used at the robot end. So, that the data from the computer

sent to the robot via WI-Fi and the digital output module 9472 will give the received control signals in the digital form to the H-Bridge circuitry.

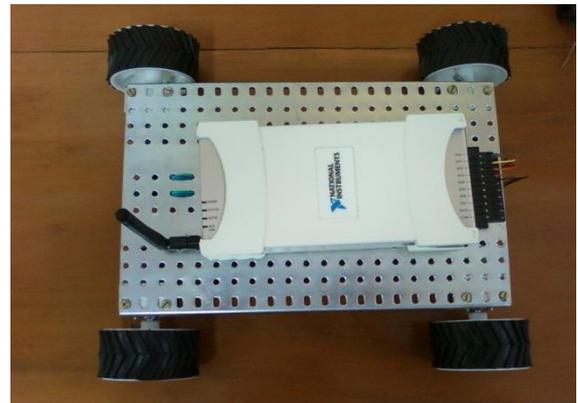


Figure 4: Mobile Robot with NI WLS 9163

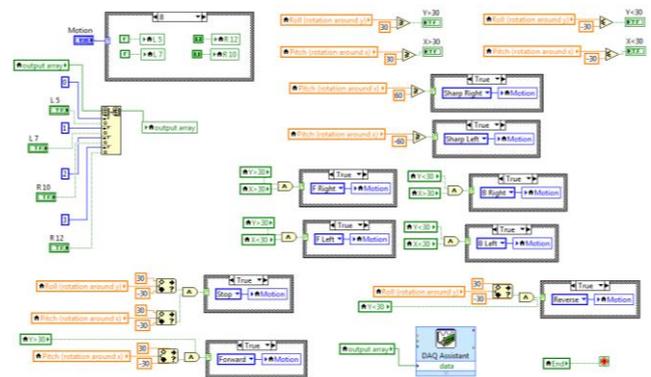


Figure 5. LabVIEW code for motor control

3.2 Setup 2: Simple PID Control

The experiment with the simple PID control is designed and published for the remote experimentation. The user controls include all the gain controls like K_p , K_i , K_d . The students can tune the system and check the tuning using the position control. The user input may vary from -90 to 90 degrees, Figure 7.

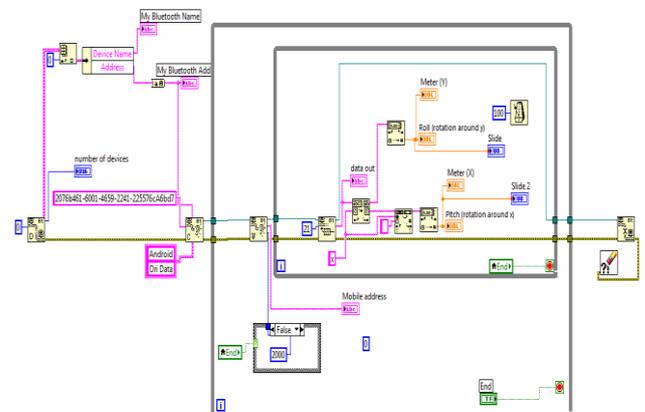


Figure 6. LabVIEW code for Bluetooth Data Reception



Figure 7. Experimental setup

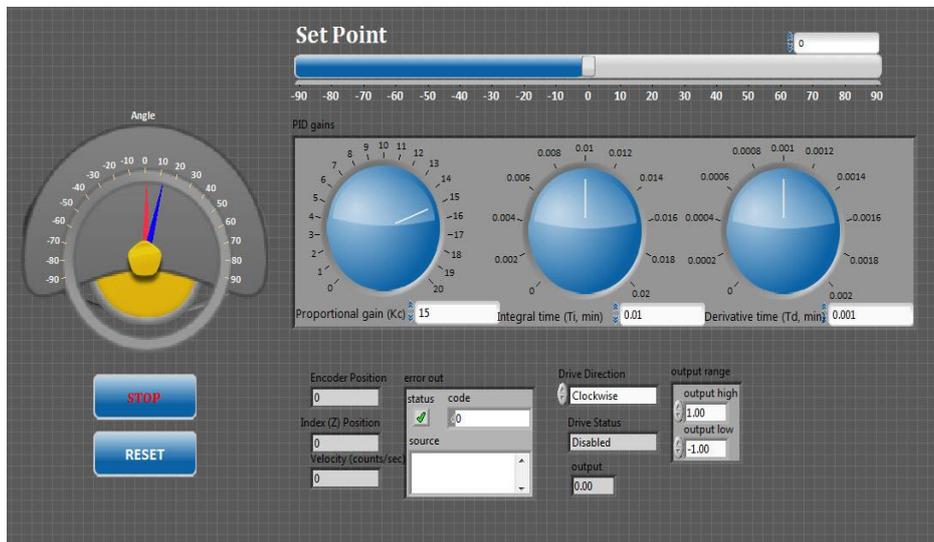


Figure 8. Front Panel

3.3 Setup 3: Visualization of Vibration and Its Control

In this research, vibration simulations and fpga based vibration control of a mass varying two-degree of freedom system was developed. The physical components of the demonstration are shown in figure 6, where a motor provides a harmonic motion to the two-dof spring-mass system [10]. As the frequency of the motor is changed, the two mode shapes can be excited and physically demonstrated online through virtual graphical user interface with real time video broadcasting of the experiment. This demonstration does an excellent job of helping the students tie-up loose ends, understand the concept of a mode-shape, & also has the advantage of introducing topics such as vibration isolation, tuned-mass dampers, etc.

The system setup consists of the following:

- CompactRIO 9012
- NI-C Series module (NI 9505, NI 9477, NI 9215)
- Laser pick-up (L-GAGE model LG10 series)
- Universal motor (either AC or DC power)
- Two Solenoid Valves
- Two Small Submersible pumps

In this project two solenoid valves and two small submersible pumps were used to control water flow in tanks. A universal motor was used to produce disturbance

at primary system. Control of valves and pumps was done by NI cRIO 9012, with different NI modules. NI 9505 was used for motor speed control by PWM generation, NI 9477 is used for digital output to control pumps and solenoid valves and NI 9215 is used for analog input from the laser pickup.



Figure 9. Experimental Setup

Pumps used here was controlled by digital output from NI 9477. The digital output was given to DC driven relays which in turn control AC pumps Figure 6. There was some delay in control system which was due to use of separate relays and due to time taken by water to reach into tank. These delays were added in program, so pump's 'ON' time was increased to compensate this delay. Figure 7 and 8 show block diagram and front panel respectively.

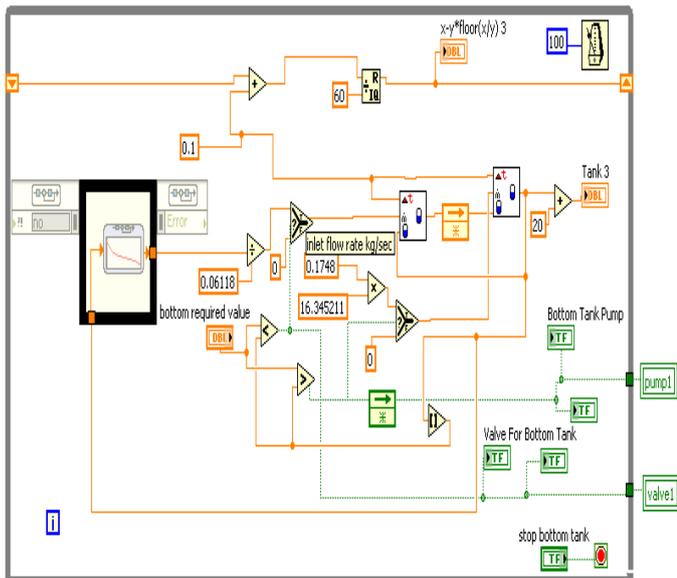


Figure 10. Water height control or mass control VI

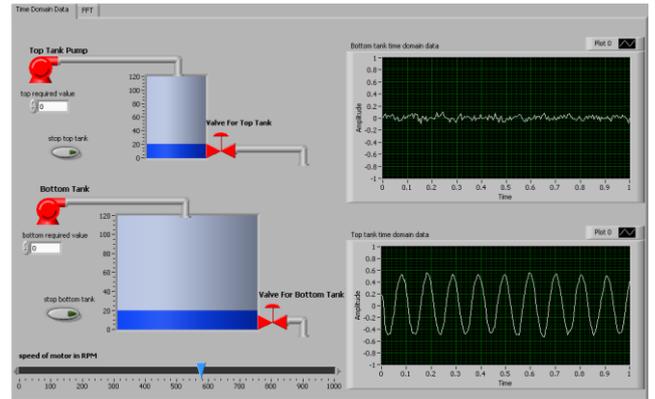


Figure 11. Front panel with time domain data and tank level control

3.4 Setup 4: Determine Fermi Energy of Metals for MSc Physics Lab

In this experiment authors developed an experimental setup using data acquisition system and virtual instrumentation to calculate Fermi energy and Fermi temperature of different materials by studying the resistance variation at different temperature. Once the temperature of the material is raised above absolute zero the Fermi energy can be used to determine the probability of an electron having a particular energy level. As equation 1 below shows, the probability that an energy state is filled by an electron depends on the Fermi energy.

$$E_f = \frac{1.36 \times 10^{-15}}{1.6 \times 10^{-19}} \sqrt{\frac{\rho AS}{L}} \text{ eV} \quad (1)$$

Where, E_f - Fermi energy of copper (eV)

ρ - Density of copper (kgm^{-3})

A - Area of cross section (m^2)

L - Length of copper wire (m)

S - Slope of the curve plotted R versus T

In metals, the Fermi energy gives us information about the velocities of the electrons which participate in ordinary electrical conduction. The amount of energy which can be given to an electron in such conduction processes is of the order of micro electron volts, so only those electrons very close to the Fermi energy can participate. The Fermi velocity of these conduction electrons can be calculated from the Fermi energy. The Fermi energy also plays an important role in understanding the mystery of why electrons do not contribute significantly to the specific heat of solids at ordinary temperatures, while they are dominant contributors to thermal conductivity and electrical conductivity. Since only a tiny fraction of the electrons in a metal are within the thermal energy kT of the Fermi energy, they are "frozen out" of the heat capacity by the Pauli principle. At very low temperatures, the electron

specific heat becomes significant. The resistance measurements were carried out on a copper sample. The experimental set up consists of Traditional ammeter and voltmeter instrument with heater.

- Keithley 2400 Sourcemeter.
- NI 9219 universal analog input module.
- NI USB carrier 9162.
- K-type thermocouple.
- Constant power supply for heater.
- PC with LabVIEW 10.0.

The block diagram of the experimental set up is shown in Figure 9. It consists of a four probe arrangement for resistivity measurement fitted with a heater having separate power supply. The maximum temperature achievable is 800 K.

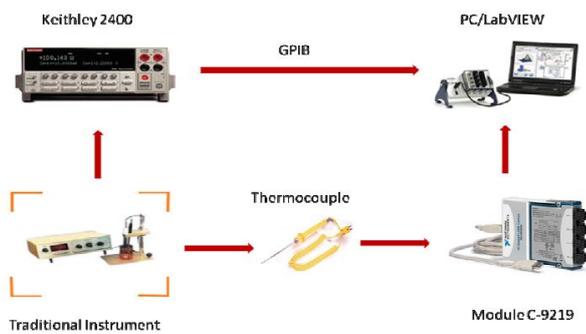


Figure 12. Block diagram of the experimental setup for resistivity measurements



Figure 13. Experimental setup for MSc Physics Lab

3.5 Setup 5: Remote Vision Integrated WiFi-based Robotic Arm

A research was done to design and build a position control robotic arm with an FPGA based real time control. Digital PWM was used to control position of servo motors to perform pick and place controlled operation, using FPGA. Integrated remote vision at the robotic arm was implemented using IMAQ toolkit in LabVIEW. To

increase speed and reliability, the joystick was used to control the robot arm from user end. The communication between the robotic arm to the computer was made possible by using WiFi router connected to the cRIO. WiFi make it to work in hazardous areas, reduced manufacturing time in industry. LabVIEW web publishing tool was used to publish GUI on HTTP for remote control of robotic arm.

Robot Arm is a 5 axis robotic manipulator, consists of a rotating base, three links and a gripper. The five axes consist of the Shoulder, elbow, wrist having 180, 300, 60 degree rotational limit with vertical movement. The axis at base is having 270 degree rotational limit with horizontal movement. The control signals to the motor define the movement of each arm in three phases.

For Wi-Fi control of robotic arm a router is used with robotic arm mounted on same station to transmit data over the Wi-Fi to the cRIO (compact reconfigurable input output device) from a remote location. Figure 11 and 12 show user front panel and robotic arm respectively.

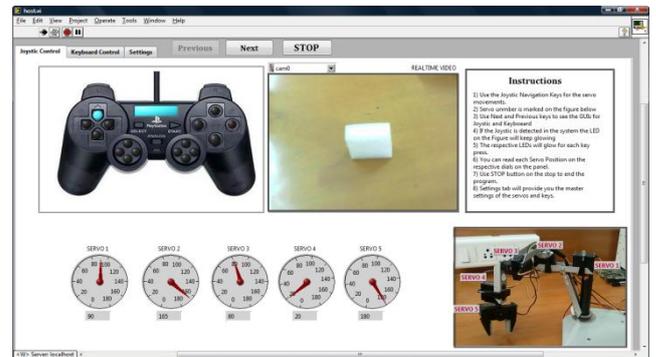


Figure 14. Front Panel for robotic arm control

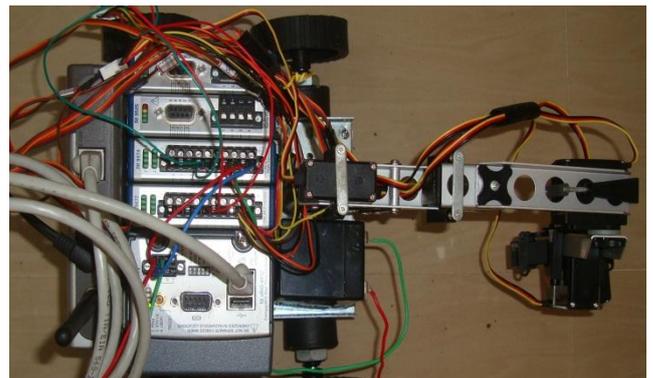


Figure 15. Robotic station with robot arm

4. CONCLUSION

Remote laboratories can be used extensively in academia to enhance classroom lectures, share research equipment, and supplement the learning process. Typical laboratories have relatively low usage, and remote laboratories can eliminate some of the barriers found in traditional laboratories. Remote laboratories can remove the need to

have a teaching assistant on hand, reduce the cost associated with a traditional laboratory, and can also be made available 24 hours a day, seven days a week. Remote Panels can take a LabVIEW program and transform it into a remote laboratory with a few simple mouse clicks. But if we need thin client application it is better to use the Web UI builder since it gives the solution for remote triggering with the Web Services.

Engineering education subject related experiments were developed. Simulations related to vibration and dynamics were developed and uploaded on the site. The attempt was to improve engineering education and technology, by effectively using technology and by engaging the student in the learning process. The main benefits of this program are: students having better problem solving skills, students build on experiences in previous courses. Students have a

stronger understanding of modeling concepts. Students have the tools that enable them to solve more difficult problems and more actively engaged in the learning process both inside out outside the classroom. This is proved by supporting survey results and students satisfaction level for different setups data shown in Table1 and Figure 16. The final and most important thing was they got virtual hands on industrial instrumentation. For education improvement in rural colleges’ workshop conducted at Government College of engineering Kannur and Saintgits College of engineering Kottayam in Kerala, India. In workshop practical demos related to mechanical vibration subject demonstrated. Finally, this paper describes the advances and improvement in remote trigger labs by demonstrating new types of engineering setups that cover wide range of engineering areas.

Table 1. Summary of Student Survey Results for Demonstration Classes

Course Information	No. of Students	No. of Questions	Very Effective	Effective	Somewhat Effective	Not Effective
Vibrations and Controls Lab, Sept 2011	20	15	7%	65%	8%	0%
Control System Lab Oct 2011	11	8	57%	37%	6%	0%
Physics Lab Apr 2011	5	4	40%	40%	20%	0%
Total	36	27	41.33%	47.33%	11.33%	0%

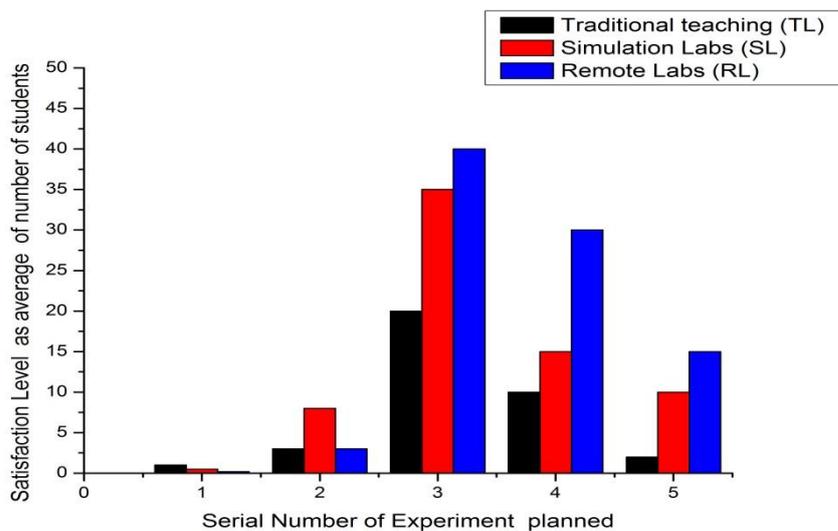


Figure 16. Graph showing the students satisfaction level

ABBREVIATIONS

LabVIEW - Laboratory Virtual Instrumentation Engineering Workbench
VI - Virtual Instrument
DAQ - Data Acquisition
CGI - Common Gateway Interface
LAN - Local Area Network
PWM - Pulse Width Modulation
C-DAQ - Compact Data Acquisition
C-RIO - Compact Reconfigurable Input-Output

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