

Running Head: VIRTUAL LABORATORY

Design and Implementation of Virtual Remote Biomedical Engineering Laboratory

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### Abstract

In this research paper, the development and implementation of Virtual Biomedical Laboratory are discussed using LabVIEW software. It is vital for the biomedical engineering to introduce the new learning environment that provides skills among students to deal with the modernized equipment. The National Instrument LabVIEW can reflect the industrial setting that gives view to the student for obtaining the real-world experience at low risk and minimum cost. The incorporation of software experience as the reflection of real world environment can significantly boost up the learning. The implementation of the biomedical based virtual laboratory that can execute the task of biomechanics, biomaterials, and bio-measurement is substantial for preparing engineering student for the industry experiences. Additionally, the development of freshman laboratory environment using LabVIEW provides the hand on experiences. Researcher utilizes unified approach and the objective is to create the experimental based learning experience using the virtual based environment. The students can login into the biomedical laboratory by using the biomedical equipment and can execute the experiment in the given time frame. The tool of Virtual instrument facilitates the hand on experience as the most significant skills interrelated with the theory and practical in the engineering studies. This research paper describes the most relevant approach to implementing Biomedical virtual laboratory and the practical application of LabVIEW.

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## Design and Implementation of Virtual Remote Biomedical Engineering Laboratory

### ***Introduction***

This research paper is focused on representing the biomedical application of LabVIEW for the biomedical engineering students, researcher, and application developers. Specifically, it is intended to show the recent development in the remote biomedical laboratory. The given lab exercises reflect the understanding of biomedical and electronics engineering fundamental concepts with the implementation of the virtual remote laboratory. The method for acquiring data, analysis, and execution of outcomes can be done using the concept and feature of the virtual lab in LabVIEW. The main subfields of biomedical engineering include biomechanics, biomaterials, and bio-measurement. Each of the subfields are interrelated with the lab exercises and each exercises comprises of the particular experimental setup. This research paper also portrays the outline of the given lab activities. The topics of EMG, EKG, tension analysis and EMG front panel are simulated using the Virtual instrument LabVIEW environment. The main objective of chosen the lab exercises is to give the overview of the graphical programming technique and error handling technique. Since all the laboratory activities are specially designed to execute at the PC system. Even, they are monitored and handled using the real-time virtual instrument having the programming setup of LabVIEW. As the LabVIEW possesses modular nature, that is the reason the experimental setup of designing and implementation can easily adapt by the institutions as the remote laboratory having modernized laboratory setup (Ertugrul, 2000, pp.171-180; Tripathi, Mohan and Gangadharan, 2012, pp.270-278). Furthermore, the same LabVIEW can be used for the generation and store the data that can modify the structure of engineering education emphasizes the students to more focus on the learning the practicality and conceptual based approach. On the other hand, this enables the students to understand the method of data acquisition. First, these lab activities represent the fundamental concept as the pillar and then proves the theoretical concept using remote based practical approach (Olansen et al., 1998, pp.279-287; McGill et al., 1982, pp.129-137).

### ***Problem Description***

The industrial environment is based on the complex system that can create challenges for the biomedical engineering students to understand the system flow and its programming. For this purpose, the Virtual instrument is selected as the most significant method to execute the lab exercises. The main reason behind choosing the concept of the remote lab is to produce the cost-

effective, flexible, feasible and safe method for the data acquisition. This virtual lab method enables to simulate the complex and high-cost system into the simplified system. Moreover, the use of LabVIEW eliminates the risk that is associated with the industrial system of high-powered running equipment.

### ***Methodology***

The concept of freshman in biomedical engineering is adapted and simulate in the virtual environment for the outcomes of the laboratory experiments illustrated in fig 1. The given lab topics are executed by the students on the weekly basis. The concept of virtual instrument become familiar by using lab exercise, Biopac hardware and software and PCs.

LAB NUMBER	LAB TOPICS
1	<b>Introduction to Data Acquisition using Biopac</b> – Introduces physiological data acquisition, analysis, and presentation using Biopac acquisition unit, transducers, and software.
2	<b>Galvanic Skin Response &amp; the Polygraph</b> – Introduces standard physiological measures using a polygraph.
3	<b>Blood Pressure and Heart Rate</b> – Introduces data collection process through recording of arterial blood pressure using the auscultatory technique.
4	<b>Nerve Conduction</b> – Recording a charge from the stimulus electrodes and determine nerve conduction velocity along the ulnar nerve.
5	<b>Electrocardiology (ECG)</b> – Provides an introduction to the electrocardiograph and the recording of the heart's electrical signal.
6	<b>Circuit Breadboard I</b> – Introduction to schematics and design of absolute value converter.
7	<b>Circuit Breadboard II</b> – Design of active filters and sine wave generators.
8	<b>Electroencephalography (EEG) I</b> - Introduces electroencephalographic sensor recording techniques and demonstrates how the brain's electrical activity varies dependent upon the task being performed.
9	<b>Electroencephalography II</b> – Students discover how the brain constantly receives sensory input and integrates the information before processing it.
10	<b>Electromyography (EMG) I</b> – Investigations of the physiological properties of skeletal muscle as well as performing signal processing analysis (i.e., FFT and RMS).
11	<b>Electromyography II</b> – Exploration of the role of skeletal muscle in performing mechanical tasks.
12	<b>Biomechanics (Goniometry &amp; EMG)</b> – Involves recording muscle activity of both triceps and biceps muscles and observing limb angular movement of the elbow.

***Figure 1-Laboratory exercise***

***Sources: (Tripathi, Jidhu Mohan and Gangadharan, 2012, p. 278)***

## ***Designing and Implementation of Virtual Biomedical Laboratory***

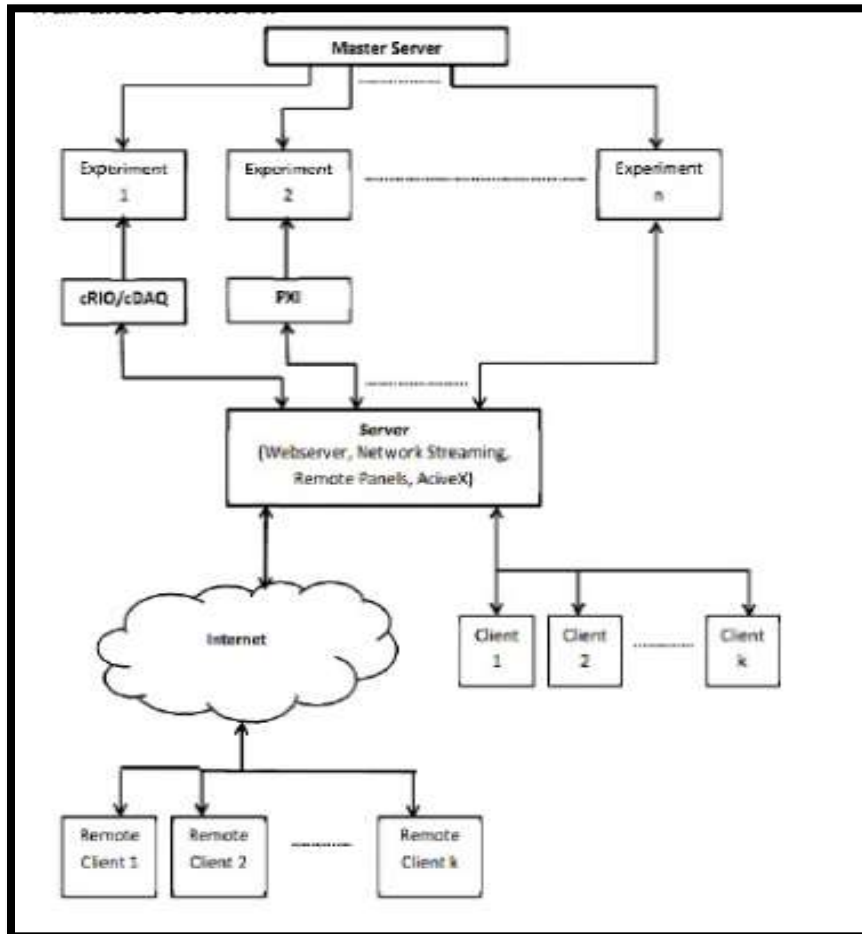
### ***Remote Laboratory Setup***

The setup of the remote laboratory is implemented using the National Instrument hardware and Lab VIEW for data acquisition. Since LabVIEW is the workbench and the coding of LabVIEW is known as the virtual instrument. The feature of the remote lab in the LabVIEW is also known as the virtual lab. The objective of using the feature of the remote lab is to monitor and control the laboratory experiment setting from the remote area by utilizing the appropriate communication technique (Ferguson and Hegarty, 1995, pp.129-160). The student can conduct the experiment by monitoring all the necessary control elements. Moreover, the exclusive video streaming feature is enabled to view the physical experimental setup. The stimulating environment is exhibited with the overall visualization and monitoring tools (Ertugrul, 2000, pp.171-180). The block diagram is illustrated in the figure 2 below. The given setup is interconnected with the servers for the controlling of the experimental progress. On the other hand, the implementation of Graphical User Interface (GUI) enables to modify the experimental parameters within no time as the architecture of virtual lab works as the fast and reliable speed.

The architecture of virtual lab consists of two main servers in which the master server handles all the important parameters. Since the reading of parameter is obtain from the relevant transducers (Webstera nd Eren, 2014, p.n.d). The occurrence of error is assumed as the exceptional case and in that condition, the master automatically takes control over entire experimental setup and its parameters. The element of exception handling is imperative as it might possible that the control is required in the external environment. It may also possible that the users or students intentionally or unintentionally mishandle the system that can become the reason of negatively impact and may cause the permanent damage. Since, it is necessary to incorporate all the software and hardware failure during the implementation of a virtual lab. For this reason, the “safe go home algorithm” is implemented to switch the laboratory experiment towards the required smooth performance in case if the error occurred (Schwartz and Dunkin, 2000, pp.218-227). After which all the controls are given to the student in case if the experiment is working under controlling criteria. The connectivity and flow of traffic will be handled by the server. Students present in the campus connect through LAN network, this provides the improved connectivity of data transfer and video streaming (Harris, Bransford and Brophy, 2002, pp.29-48). Moreover, the client can also access the laboratory experiment by using the

website resource. For controlling the experiment remotely, the various technique can be used which are given below:

- Adobe flash mode using Web service
- UI mode using Web service
- The CGI-based server technology
- The Built-in LabVIEW based Web server (Remote Panels)



*Figure 2- The block diagram of remote lab*

*Sources: (Tripathi, Jidhu Mohan and Gangadharan, 2012, p. 278)*

### *Remote Panels*

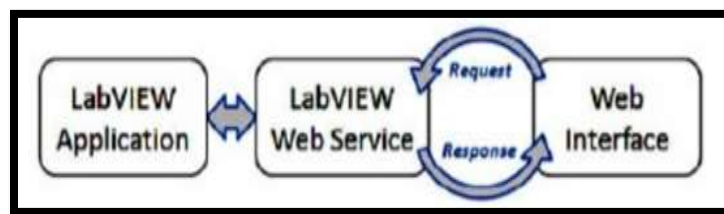
The implementation of the remote panel is assumed as the most simplified method for interfacing the remote access using World Wide Web. The images of the panel are constantly sent to the user using the web services having a minimum period of time. This is the most



simplified method as the broadcasted panel is configured using LabVIEW web server environment. Since, the disadvantage is that student cannot intermingle with a virtual instrument (National Research Council, 2000, p.n.d).

### *Web Services*

In this method, standardized website based protocol enables the remote connectivity. First, student directs the connection request towards the remote server, server process the given request and provides the responsive interpretation that usually showed by the application. The same method of connectivity is utilized in all the internet related actions such as the website browsing and emails receiving. Since the website services work as the API (Application Programming Interface) towards different software whether it's purpose is to execute the complex system or storing the simplified data. For using web service accurately, the student has mentioned the connectivity request towards the hosting medium which is a remote system, after processing and executing the request response is send through XML. Then, the student can select the display method according to the requirement in form of XML raw data. However, the most common practice is to analyse and view the data being a part of Graphical User Interface (GUI) as shown in the below figure 3. The other method is UI builder, it is the LabVIEW-based website editor that focuses on implementing the represent data in using knowledge of graphical programming for the development of less memory consumed application that also reachable using website browser.



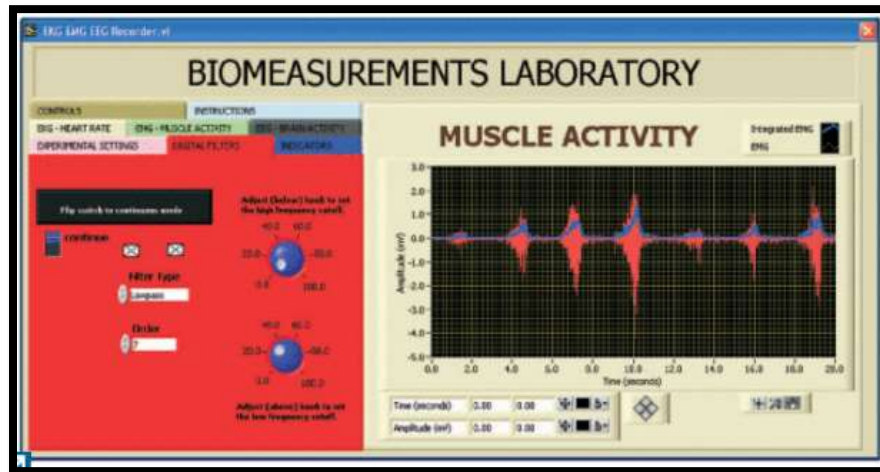
***Figure 3- Web interface connection***

***Sources: (Tripathi, Jidhu Mohan and Gangadharan, 2012, p. 278)***

### *Bio-measurement Laboratory*

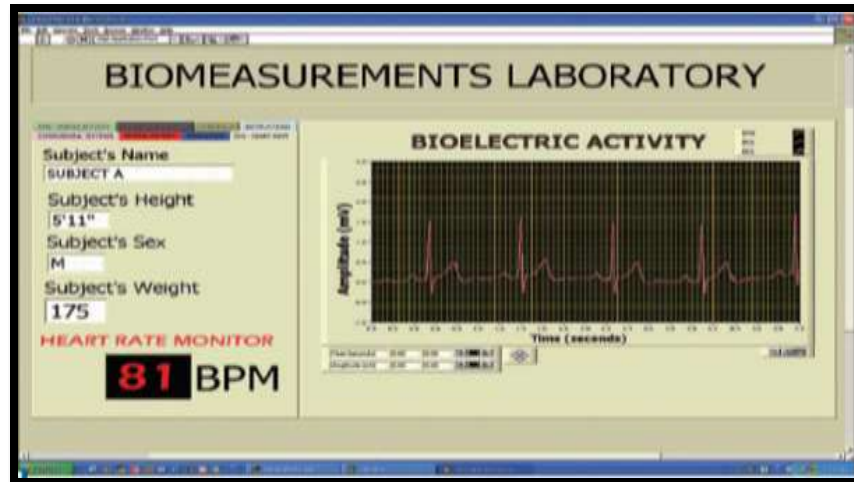
For covering the basics of bio-measurement and rules of the patient safety, the design system is based on the measurement of physical quantities by applying various methods such as the noise detection using mechanical devices and electronic equipment. The results of

experiment analyzed using mathematical models. A further measurement is made by executing the graphical programming and DAQ programming. For measuring the physical quantities, the virtual based power supply, oscilloscope, filter and functional generator are selected using LabVIEW. Using the same environment, the task of hardware testing, monitoring, controlling and system analysis is being performed. The presence of Booleans expression, string, and numerical indicator give the access to the LabVIEW graphics and provide the analytical approach to observe the electronic concepts. In the illustrated figure, the example of implementing the virtual bio-measurement laboratory are indicated that record the EMG (Andre, 1997, pp. 28-34).



*Figure 4- EMG recording using Virtual instrument*

*Sources: (Author Own)*

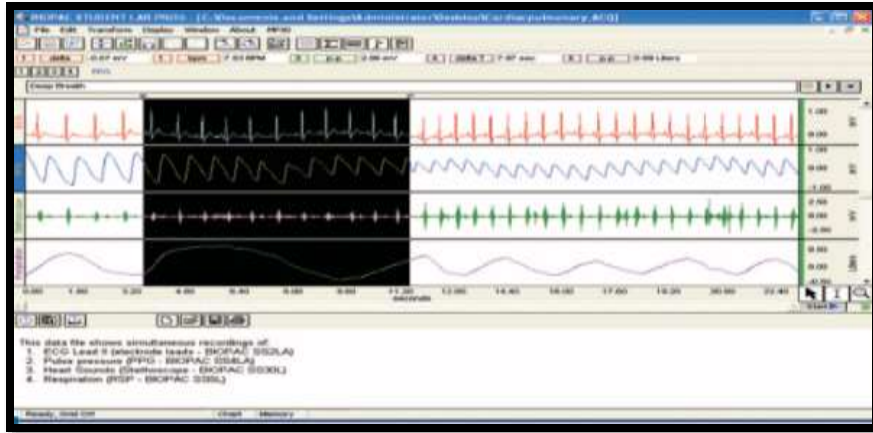


**Figure 5- EKG recording using Virtual instrument**

*Sources: (Author Own)*

### *Biomechanics Laboratory*

The virtual based biomechanics laboratory focuses the theoretical information related to the soft bone and tissue. The significant topics are biofluids, biosolids, and biodynamics. Using the Virtual instrument the setup design in such way that can fulfil the requirement of structural interaction. This virtual laboratory uses the LabVIEW environment to obtain the readings of motion acquisition, the modelling of musculoskeletal, strain gauges and the force of load cells. For this purpose, the recorded reaction is taken by the force transducer while making the contraction and relaxation activities of muscles such as bicycling, walking and setting. The setup of biodynamics motion is simulated using a virtual instrument (Buckman, 2000, pp.228-233). Furthermore, for the gait analysis digital camera is interfaced using NI vision builder. For the determination of standard gait cycle, the video has captured the motion as well as the acceleration, speed, and velocity while the completion of one complete gait cycle. In the end, the data is compared using the tool of LabVIEW data analysis.

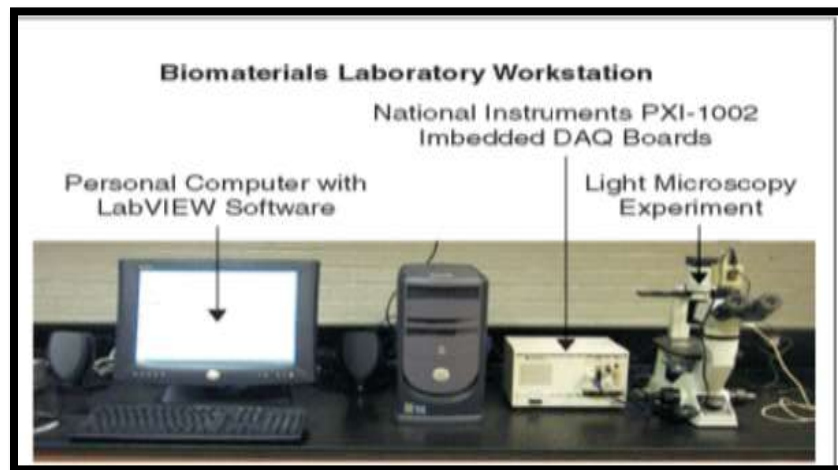


**Figure 6- EMG front panel for Biomedical laboratory**

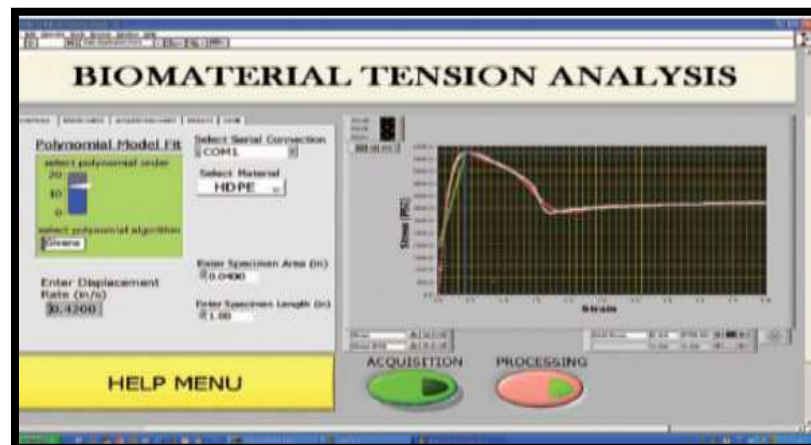
**Sources: (Authors Own)**

### *Biomaterials Laboratory*

The purpose of virtual biomaterials laboratory is to observe and analyse the structural properties of various materials utilize in the manufacturing of electronic and medical equipment. Special focus is highlighted towards the problem related to the biocompatibility, mechanical and structural properties of the biological system and its effect on the materials. For achieving the task, a user-defined method is used for the testing and analysing the materials. Moreover, the stress and strain analysis are executed for the tissue modelling and acquisition. The illustrated figure 7 and 8 is conveying the information regarding setup related to the biomaterials workstation. The given step up possesses the capability to innovate the development in the testing of material. As the laboratory task, students should design and implement the complete LabVIEW functions that can reflect the objective of material testing and accomplish the analysis of stress and strain on the numerous biomaterials. The LabVIEW instrument enables to analyse the bending, fatigue pattern, bone fracture and effect of the biomaterials such as polymers, titanium, and fixtures (Olansen, Ghorbel, Clark and Bidani, 2000, p.n.d). The feature of IMAQ vision in LabVIEW facilitates to observe the outcome of biomaterials subjected to the light microscopy. The aim of observing the material under light microscopy is to obtain, examine and evaluate the biomaterial images. The designed biomaterial laboratory provides the element of vision, pattern comparison, color effect, and application development. For the quantification determination, the students can create the user defined function for histologically compares the IMAQ (image acquisition) and tissue sampling.



*Figure 7- Workstation for biomedical laboratory using VI*  
*Sources: (Tripathi, Jidhu Mohan and Gangadharan, 2012, p. 278)*



*Figure 8- Tension analysis using biomaterial laboratory*  
*Sources: (Author Own)*

### **Discussion**

The field of biomedical engineering is progressively developing as the demand from the industry is rapidly changing. The implementation of LabVIEW and virtual instrumentation delivers the most reliable, authentic, flexible, low-cost and approachable method for simulating the biomedical laboratory test environment. The future research is suggested that the latest

technological advancement producing the high demand of cost-effective solution for the analysis the response and its outcome. That is the reason, the Virtual instrument is considered as the most effective and efficient environment for interfacing and simulating the complete biomedical system using the inexpensive method. This prepares the engineering students to visualize the industrial principles and theoretical implications. Using this unique approach, students accept the modification, laboratory setting and encouraging their understanding related to biomedical engineering equipments. The practicality of the LabVIEW program along with the hand on experience on the virtual instrument is significant for the success of biomedical graduates (Enderle, Ropella, Kelsa, and Hallowell, 2002, pp.59-66). The students need to become proficient in the simulation of LabVIEW tasks as the preparation to handle the industrial based real world experiences (Rosow, Adam, Coulombe, Race, and Anderson, 2003, pp.58-76).

### ***Conclusion***

In the concluded statement, it is necessary to mention that LabVIEW is the most powerful analytical and simulation tool for the engineering education. This tool can be utilizing to observe the response of any system before implementing the huge hardware system. It is highly recommended for the student to learn about the detailed description of LabVIEW programming along with the overview of LabVIEW system. The designed and implemented biomechanics, biomaterials, and bio-measurement laboratory can be used as the instructional guidelines to execute the laboratory setups and biomedical exercises. The objective of creating the general purpose biomedical laboratory is to given the overview to the student about the existence of practical application in the test environment. The given virtual instrument facilitate the university students to record the readings using the global LabVIEW variables by obsoleting the complexity of the system. Moreover, students can also learn to debug the error while executing the LabVIEW program that can improve their fundamental biomedical concepts. The implemented designs in this research paper can provide the interactive view about the basic electronic concepts related to the biomedical field. This also become the reason of polishing the student knowledge and enhancing the student mind to supervise the virtual system while working on the laboratory research. Although, the laboratory exercises require the information about system designing and its performances. Compiling the electronic theories with the biological responses can create the collaborative approach for the development of biomedical experiments. The acquisition, monitoring and controlling approach boost up the experiment quality. The

development and implementation of the biomedical experiments of such nature transform the complexity of the system.



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