

# Virtual Lab: Real-Time Acquisition and Analysis of ECG Signal

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**Abstract**—Sole motive of this work is hardware/data resource sharing over internet for academic/lab experimentation purpose. In India, major problem with the education system is lack of practical knowledge due to unavailability of resources. Without practical implementation, students find difficulty in correlating their theoretical knowledge with real world problems. Thus to tackle this situation, “virtual labs” are developed with an intended idea to support and upgrade the quality of education in engineering colleges where lack of practical facilities hinders growth of technical education among students. This facilitates the involvement of students in gaining practical knowledge i.e. working of an ECG machine, impact of various signal conditioning techniques on acquired signal, and to observe ECG waveform of a patient in various conditions.

**Index Terms**—NI LabVIEW™ 2009, ECG signal analysis.

## I. INTRODUCTION

In India, one of the major bottlenecks in the path of complete technical education is lack of resources necessary for practical education. Because of lack of financial resources students are not introduced to sophisticated industrial instruments. This absence of practical experience hinders the overall techno-intellectual growth of students. Sometimes unavailability of sufficient quantity of resources avoids students from learning together and sharing experiences. To tackle such problems the only solution could be the development of a system allowing simultaneous multiple access to instruments without disturbing each other’s work. One such solution has been proposed in this paper where parallel access to an instrument is possible.

The proposed system will facilitate an actual lab like environment where a student will be able to operate an instrument, record data, analyse data and then make proper report of the observation so made, that also just on a ‘click of mouse’. The system is supposed to work in two parts:

### A. Server Application:

This part of system is being operated in central Laboratory where the server is actually connected to Biopac™ MP150 ECG system and Fluke PS-420 Multi-patient ECG simulator. This system continuously publishes ECG multi-channel signal acquired from the software controlled multi-patient ECG simulator at a desired sampling rate. It also acts as a connecting link between remote user and central database system. The system publishes live video of laboratory to let the user observe the changes in the hardware activity with the commands given by the user over the internet. It also performs the task of an online time slot

booking as per choice cum availability of time slot by the remote user.

### B. Client Application:

This application will ‘contact’ the server application to facilitate operations at the user end serving the purposes such as slot booking, data acquisition, recording, analysis of ECG signal and report generation of the observation made by the remote user connected through the internet. For assessing user’s understanding from the performed experiment the application also contains an optional module for multiple choice questionnaires based on random questions picked from a pool of ECG related questions stored and published by the server application. It includes facilitating remote end users with freedom to book a time slot according to their need and availability. To avoid ambiguity in hardware command handling, only one user (‘active user’ as per time slot booked) can control the hardware. Other users at the same time can also perform the experiment by acquiring data but they won’t be allowed to change the settings of system through hardware control.

## II. SYSTEM CONFIGURATION

The system hardware consists of:

- Biopac™ MP150 12-lead ECG acquisition system
- Fluke™ PS420 10-lead ECG Simulator
- Dlink™ DCS-5220 IP surveillance Camera.
- Server Workstation

The Biopac™ MP150 is a 16 channel multi-parameter biomedical signal acquisition system works at various sampling frequencies over Ethernet connection. The system can be used to acquire real time 8 channel ECG (Lead I, Lead II and Chest 1-6 leads) in LabVIEW™ by using a software package called as Biopac™ Hardware API (BHAPI™). BHAPI facilitates acquisition of ECG signal at desired physical channel and at desired sampling frequency in LabVIEW™. Hence BHAPI helps in realization of software control on Biopac™ MP150 system.

Fluke™ PS420 is a 10-lead multi-patient ECG Simulator capable of simulating ECG signal corresponding to around 120 diseases at eight different beat rates and three different amplitude levels. The simulator is capable of communicating with PC over RS-232 serial link providing a software control to change ‘ECG subject’ as and when needed.

D-link DCS-5220 is an IP surveillance Camera and publishes real-time video over internet. This camera works as an HTTP server with camera pan/tilt functionali-

ties and hence can be called using LabVIEW™ to show Lab’s live video at remote end.

All the three system components together facilitate a remote end user to

- Control Instrument (data acquisition system)
- Control Data to be acquired
- View real-time Laboratory Video

Hence provide a real lab like environment, thereby allowing students to use real instruments kept at a remote.

The server workstation is powered with Intel™ Xeon™ 2.27 GHz (2-processors with 4 cores each) and memory of 4GB. The server is connected to internet through 1Gbps leased line.

### III. SYSTEM IMPLEMENTATION

The system works in two parts i.e. the Server and the Client Application. The Server application serves the purpose of data publishing, login handling, hardware control and slot booking. The Client end application facilitates remote end user to book a time slot for controlling hardware, login handling, data recording and analysis and report generation of the experiment.

The server application is based on a ‘state model’ and works in 3 working states namely

- Home State
- Admin State
- Data Server State.

Each working state performs a specific task and provides a specific control set to the system administrator operating the server application. The working state transition solely depends on the operations performed by the administrator. Figure 1 shows the allowed state transitions of the server application.

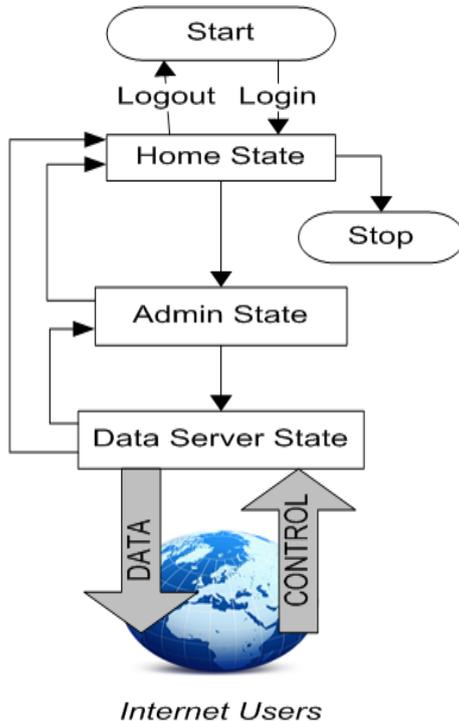


Figure 1. State flow diagram for server application

#### A. Home State

The Home State is the first state encountered by the system when started. It allows the user to operate the system only when he/she provides a valid administrator username and password stored in a centralized database system. If a valid administrator user logon to the system then this state provides options like manipulating the user time slots, moving to the next working state and putting system on standby state. Figure 2 shows options available to the administrator in front panel of the server application in home state.

#### B. Admin State

This state allows the user to exercise his/her rights of being system administrator. It provides options platform to communicate to remote end users via email and to change the remote user information stored in database. It also provides a facility to debar remote users from connecting to the server application. Figure 3 shows front panel setup for admin state.

#### C. Data Server State

As the name suggests this state make the system act as a server. After entering into this state the system start continuously acquiring real-time ECG data from Biopac™ MP150 system at a desired sampling frequency and publishes the data on Internet using ‘one to all’ TCP-IP communication.

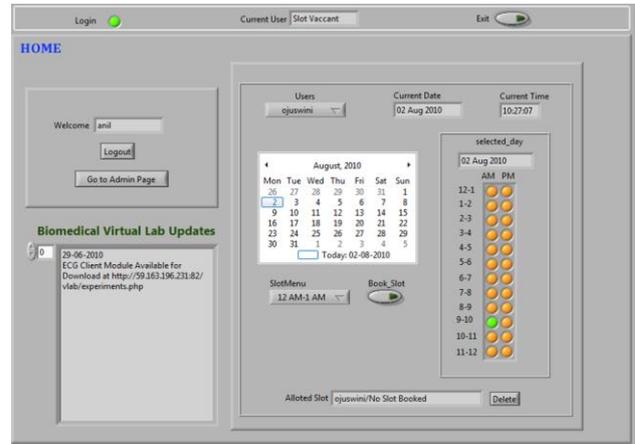


Figure 2. Front panel of the server application in home state with valid user logged ON

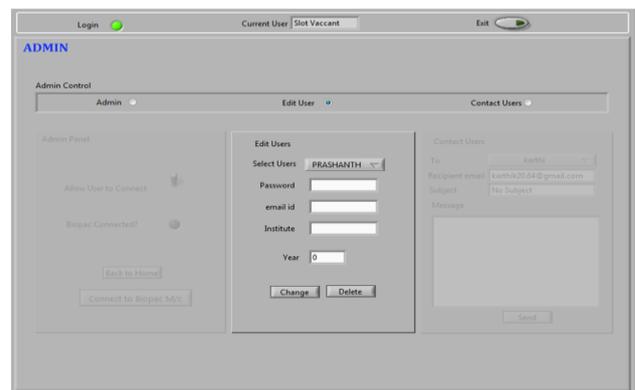


Figure 3. Front panel of the server application in admin state

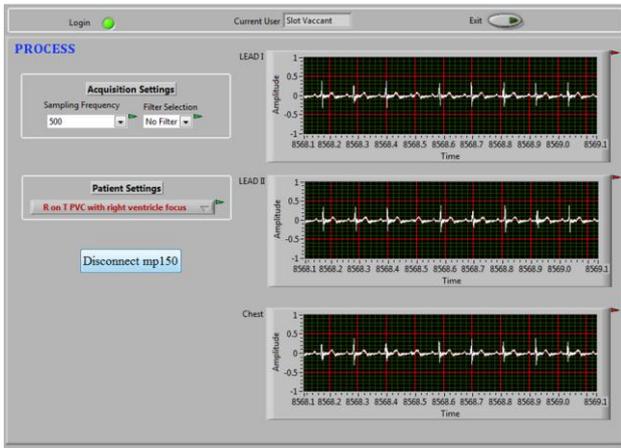


Figure 4. Front panel of the server application in data server state

System keeps on checking the time slot booking/deletion requests and make appropriate entries in database to keep a record. The system also keeps a track on Current ‘Active User’ and publishes the corresponding username. The Active user is granted permission to change Simulator Settings and Sampling Frequency of the data acquired. The acquisition settings like sampling frequency, filter selection and patient settings are shown in Figure 4. This can only be changed either by active remote end user or manually by server administrator.

IV. CLIENT APPLICATION

The client application is also based on a state model similar to server application. It works in six working states namely

- Home State
- Data Acquisition State
- Data Review State
- ECG Analysis State.
- Evaluation State
- Report Generation State

The client application connects the server application through shared variables with the help of Data Socket toolkit of the LabVIEW™. Most of the processing for the experiments is done on client end only thereby enabling the server to serve more users concurrently. Figure 5 shows the allowed state transitions of the client application.

A. Home State

The operation of Home State of client application is same as that of server application. The only difference is that instead of directly connecting to database server, it connects server application to use database thereby limiting the user’s access to central database system. It provides some of the basic options to the users such as Log-in/Logout, time slot booking/deletion, connection to data acquisition etc. Figure 6 shows the front panel of this state.

B. Data Acquisition State

The data acquisition state basically deals with acquisition of data for recording and analysing for experimentation purpose. It provides two modes of data acquisition i.e. online and offline mode. Offline mode allows the user to

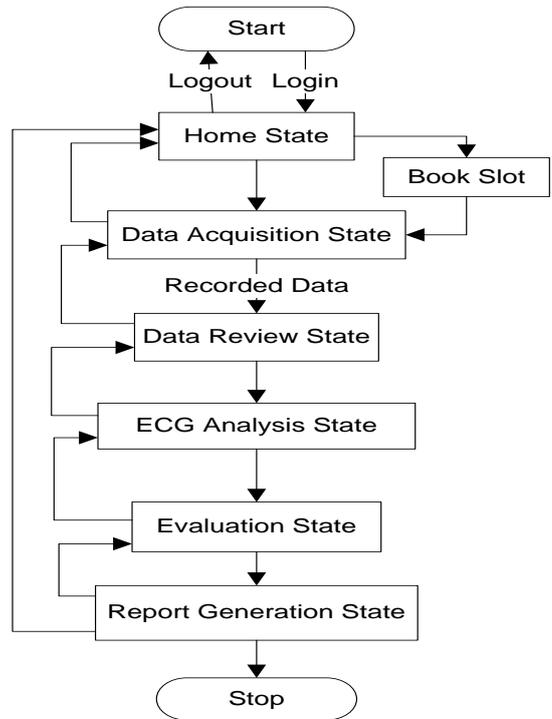


Figure 5. State Flow Diagram for Client Application

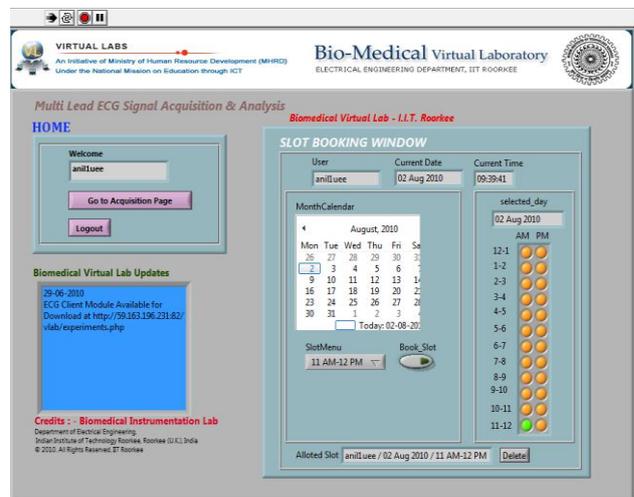


Figure 6. Front panel of the client application in home state in valid log on state

use pre-recorded ECG data file as data source for ECG analysis and experimentation. Online data acquisition mode establishes a TCP-IP communication with the Server application and retrieves real-time 8 lead ECG data for analysis and experimentation. Before starting any online acquisition it allows the ‘active user’ to change the sampling frequency and patient simulator settings.

The user can set the recording duration and hence record desired length of ECG signal in the form of a spreadsheet file. Selection of offline mode skips the data acquisition part and takes the data from specified file as recorded data to be used for analysis. Fig.7(a, b) show front panels of this state. The controls for patient simulator setting and acquisition settings are enabled for the active user only. It is disabled for other normal users i.e. the normal users can’t control the hardware.

C. Data Review State:

In this working state the recorded 8 Lead ECG is transformed to obtain 12 Lead ECG signal using Einthoven's Triangle Law. This state allows user to view all 12 ECG leads simultaneously. This enables the user to understand the impact of the disease on ECG waveform thereby providing a real lab-like environment. Figure 8 shows front panel of this state.

D. ECG Analysis State

This working state analyses the recorded ECG signal for Heart Rate Variability (HRV) analysis. Under this state the data is analysed for detection of various wave components and measurement of diagnostic important parameters as well as HRV analysis. For HRV analysis the R peaks are detected in Lead II of the ECG recording using wavelets and various statistical parameters are calculated for RR intervals to study heart rate variability. Figure 9 shows front panel of this state.

E. Evaluation State

This state offers a questionnaire as shown in Figure 10 of ten randomly selected multiple choice questions from a predefined question bank to evaluate a student's under-

standing from the experimentation. After questionnaire the user is required to provide his/her comments.

F. Report Generation State

It is the final working state of the client system which compiles all the inputs to select data acquisition parameters, important waveform charts and results to create a report for the experimentation. With the help of report generation toolkit in LabVIEW™ an html page based report is displayed in a web browser active X control object. Figure 11 shows the experiment report generated for a sample experiment.

I. BENEFITS OF USING GRAPHICAL SYSTEM DESIGN APPROACH

Graphical System provides both controls and output results on same screen and hence makes the system easy to understand and use.

LabVIEW being a parallel programming paradigm makes virtual instruments more realistic by executing parallel operations simultaneously.

Graphic design allows the remote end user to observe data loss during network transmission in the form of distortion in ECG waveform.

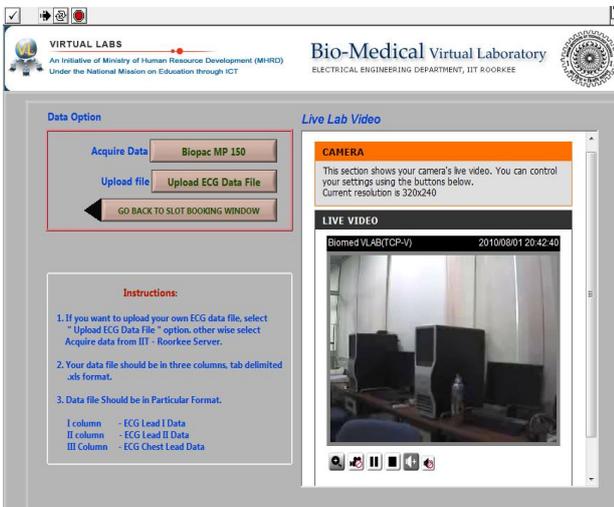


Figure 7 a) Front panel of the client application in data acquisition state

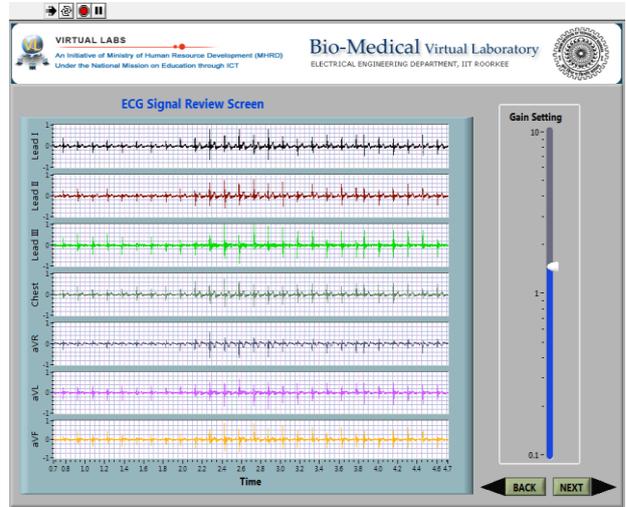


Figure 8. Front panel of the client application in data Review state

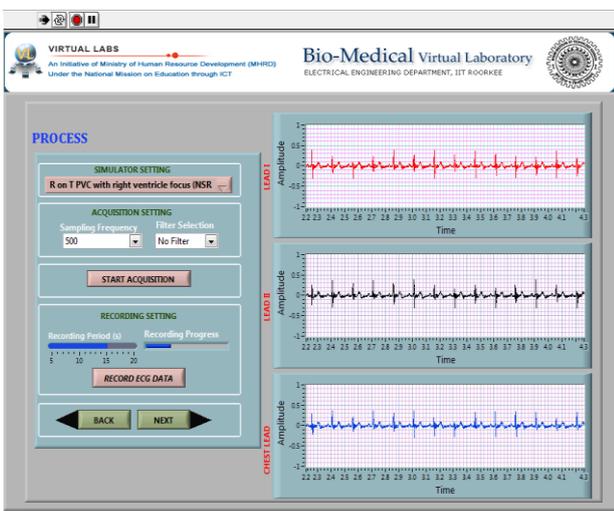


Figure 7. b) Front panel of the client application in data acquisition state (Online Mode)

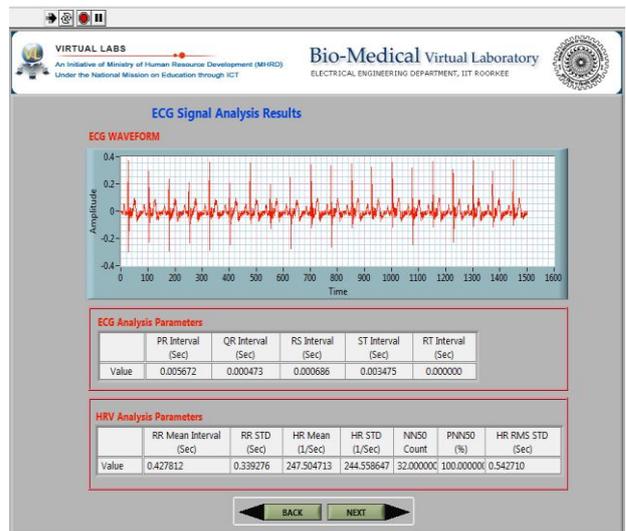


Figure 9. Front panel of the client application in ECG analysis state

Figure 10. Front panel of the client application in evaluation states showing questionnaire page

Figure 11. Front panel of the client application in report generation state

## II. BENEFITS OF APPLICATION

Since the system is designed for teaching and learning purpose so efforts have been made to give details of experiments, background material in form of pdf files, uploading and downloading human ECG data enables students to understand practical electrocardiography in a better way. As far as resource utilization is concerned the proposed system of Virtual experimentations outperforms traditional experimentation in following ways.

- Single hardware is being used by multiple users, without any kind of interference in each other work.
- Highly cost-efficient since only a computer with internet connection needed to use the system.
- Because of being connected to the central database system there is minimal manual input.
- The live video streaming feature of the system can be used for live demonstration/lecture there by filling the gap of being physically present in the process of lab experimentation.
- System being available on internet allows anyone to use the expensive instruments anywhere and any-time.

- HTTP based chat facility is available to get live technical support from technical staff at lab.

## III. CONCLUSION

The proposed system presents a new technique of lab experimentation which is highly cost effective. By providing availability of costly instruments to students over internet this system will be cost effective and facilitate students to have quality education. It would revolutionize the technical education system. As a result, the beginning of a new era to provide laboratory facilities to students 24x7 days is possible.

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## REFERENCES

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