Online EEG Experiment using Virtual Labs Architecture

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Abstract

Electroencephalography (EEG) is a non-invasive recording of electrical activity of brain on scalp. Because of its uses in clinical diagnosis and conventional cognitive neuroscience, EEG is an important subject for medical students and biomedical engineers. Availability of a standard acquisition device and data is major bottleneck experimental learning which restrains students from correlating their theoretical knowledge with real world problem. As a solution, this paper presents an online EEG system based on virtual labs architecture for remote experimentation. The presented system provides undergraduate and postgraduate students with standard EEG data and helps to learn practical aspects of electroencephalography i.e. working of an EEG machine, impact of various signal conditioning techniques on acquired signal, and to observe EEG waveform of a patient in various conditions.

Index Terms: Virtual Labs, NI LabVIEW™ 2010, EEG signal analysis.

Introduction

In most of the developing countries, lack of resources necessary for practical education is of the major challenges faced by technical education. In such countries most of educational institutions do not have access to sophisticated industrial instruments; this absence of practical experience hinders the overall techno-intellectual growth of students. This unavailability of sufficient quantity of resources avoids students from learning together and sharing experiences which is not possible through theoretical knowledge available through books alone. Solution to such problem lies in development of systems facilitating hardware sharing and remote access to educational resources through virtual instrumentation. For best utilization of these resources, such virtual systems should allow simultaneous multiple accesses to remote users 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 is aimed to provide an actual lab like environment where a student will be able to operate a biomedical instrument, record and analyse live EEG data and then make proper report of the observation.

Virtual Labs Architecture

The presented online EEG experimentation system is based on Biomedical Virtual Lab architecture originally proposed by Kumar et al. [1]. The proposed system works in two parts named:

- Server Application
- Client Application.

Server Application

This part of system is operated in Biomedical Instrumentation Laboratory at IIT Roorkee. The server system connected to Biopac™ MP150 EEG acquisition system [2] and Grass Technologies 32 channel EEG simulator [3]. This in IIT Roorkee system continuously publishes live EEG multi-channel signal acquired from the EEG simulator at a desired sampling rate. This application provides access of all laboratory resources and central information system. To allow remote users to observe hardware response to the online commands, the system facilitates live video streaming of the lab through IP camera. To avoid any conflict between simultaneous users the system facilitates online time slot booking as per choice cum availability of time. This way only at a time one user (referred as ‘active user’) having time slot booked can manipulate hardware and acquisition setting, whereas the data is available to all users and hence all users can perform experiments independently. The system hardware (Fig. 1) consists of:

- Biopac™ MP150 20-electrode EEG acquisition system using 10 EEG100C amplifiers.
- Grass technologies 32 channel EEG Simulator
- Dlink™ DCS-5220 IP surveillance Camera.
- Server Workstation (Dual Intel Xeon 2.27 GHz 4 cores processors, 4 GB memory)
Client Application
The client application works at remote user end and connects remote users with Server Application. It provides various functionalities like slot booking, data acquisition and control, recording, analysis of EEG signal and report generation of the observation. To ensure proper learning of student, relevant theory and literature regarding EEG provided with experimentation package. After experimentation the users are offered a questionnaire related to the experiment performed to test their learning. Finally after performing the experiment, the system generates experiment report showing the data waveform, experiment analysis and questionnaire results.

System Implementation
Server Operation
Similar to the server system developed by Kumar et al. [1], the server for this system also works in 3 states viz.
- Home State
- Admin State
- Data Server State.

Fig. 2 shows the possible state transitions sorting operation of server application. The home state facilitates an authenticated server administrator to Add/Edit time slot booking for remote users. Under Admin State, the administrator can exercise administrative rights like:
- Adding/Deleting remote user accounts
- Generating statistical logon report of remote user on virtual lab server
- Communicating remote user by sending email
- Blocking remote users from connecting to server

During the data server state, the server application acquires 20 electrode data out of available 32 electrode ports available in Simulator. The data acquisition on simulator follows internationally 10-20 EEG system and form 10 analog channels in bipolar (differential) acquisition mode. The data publishing and control transfer takes place using NI DataSockets™ based variable sharing [4]. Fig 3 shows front panel of data server state of EEG server.

Client Operation
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
- EEG Analysis State.
- Evaluation State
- Report Generation State

Out of these operation states, Home state, Data Review state, Evaluation state and Report Generation state have been adopted from the base architecture [1]. Therefore this paper discusses Data Acquisition State and EEG Analysis in detail. Home state is the first operation state encountered to Client.
Application and it automatically tries to contact server application and retrieves login information. It allows remote users to login to virtual labs system and book a time slot in central database to work as active user.

Data Acquisition State provides two modes of EEG data acquisition for experimentation and analysis i.e. online (from virtual lab server) and offline (local system resources). In online mode Active users have access to change acquisition settings in terms hardware sampling frequency. Client application allows users to acquire data at four pre-set sampling frequencies viz. 100Hz, 200Hz, 500Hz and 1000 Hz.

Users can select the acquisition depending on analysis and internet resource availability and record the data for desired length (up to 300 s) for analysis. The system saves the recorded data on local computer in form text file and initiates its playback for user’s approval. Fig. 4 shows from client user interface in online data acquisition mode.

![Fig.4: Front panel of EEG data acquisition](image)

The EEG analysis state has been designed to help students to learn variation in EEG in spectral and statistical domain with different neural activities. During analysis student also get opportunity to verify the processing by testing on standard signals comparing with the results obtained through acquired EEG data. Fig. 5 shows front panel of the EEG analysis mode in client application. Following EEG analysis tools are provided to remote users:

![Fig.5: Front panel of EEG analysis](image)

**Spectral Analysis**

Since different neural activities appear in EEG in different frequency range and at different locations. The users can select any EEG channel and can obtain following standard EEG wave components:

- Alpha wave (8-13 Hz)
- Beta wave (30-100 Hz)
- Gamma wave (13-30 Hz)
- Delta wave (0-4 Hz)
- Theta wave (4-8 Hz)

Apart from these standard wave components, used have freedom to design a filter of their desired specification and use it obtaining custom EEG component wave. The available filter types are

- Butterworth Filters
- Chebyshev Filter
- Elliptic Filter
- Bessel filter

Users can design a filter of desired order and pass band and see the filtered output in available mixed graph.

**Statistical Analysis**

Apart from spectral features, statistical features also vary with neural activities in brain. The proposed system allows users to apply statistical filters like Standard Deviation, Median, Variance, Local Maximum, Local Minimum and Local Mean on selected EEG channel in a moving window mode. Users can select any window size of their desire and observe the statistical variations in EEG.

All the analysis done by users is automatically forwarded to an inbuilt experiment reporting mechanism. After analysis, users are offered a questionnaire of ten randomly picked multiple answer type questions. Since the system has been designed to cater needs of educationalists and teachers in teaching and training, questionnaire helps in accessing practical learning of students. Finally after experimentation the experiment report (Fig. 6) is made available to users which can be easily printed as record.

![Fig.6: Report generated after performing experiment](image)
System Implementation

Since lab experimentation need high end Graphic User Interface (GUI) and parallel processing capabilities, NI LabVIEW™ has been used to develop this experimentation architecture and virtual instruments. The client application is free available for use can be downloaded from http://210.212.58.232/vlab after registration from the same website. The necessary documentation and technical theory regarding the experiment is provided on website to support students in correlate theoretical knowledge with practical experience. The application works well on Microsoft Windows™ (XP or newer) operating system.

Conclusion

The online experimentation system presented is paper proposes a highly cost effective means for promoting Distance Education. Since only a computer and internet connection is required for perform experiments over virtual labs, the presented system offers a facility to perform experiments anywhere and anytime and hence will revolutionize the technical education system. Attempts are being made to make EEG simulator computer controlled so that students can change the EEG data on their own.

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References


Authors Biography

Anil Kumar completed his Bachelor’s degree in Electrical Engineering from Indian Institute of Technology (IIT) Roorkee and is working as Junior Research Fellow at Biomedical Signal Processing Lab, IIT Roorkee, India. His research interest includes Machine Learning, Biomedical Signal and Image Processing, Autonomous Robotics, Computer Vision, Computer Aided Instrumentation and Software Application Development. He has successfully completed major projects sponsored by IRDE Defense Research and Development Organization (DRDO India), Rajasthan Electronics and Instruments Ltd. (India) and Ministry of Human Resource and Development (MHRD) India.

Jagannath Malik is pursuing Integrated Dual Degree (Bachelors/ Masters) in Electronics & Computer Engineering with specialization in Wireless Communication at IIT Roorkee, India. His research interest includes soft computing techniques, artificial neural networks (ANNs), optimization algorithms, image processing, millimeter-wave engineering, metamaterial, microstrip antennas for communications, RF and microwave designs. He has published a number of papers in the fields of ANN and microstrip antennas.

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Vinod Kumar is Professor and head of Electrical Engineering Department, Indian Institute of Technology Roorkee, India. He is also head of Continuing Education Centre and Quality Improvement Program Centre of IIT Roorkee. He received his both Masters and PhD degree from IIT Roorkee (erstwhile University of Roorkee). He has many academic awards, distinctions and scholarships and more than 150 research papers to his credit. He has 34 years of rich experience of teaching & research. He is a life fellow of IETE and is a senior member of IEEE. His areas of interest are Biomedical Signal and Image Processing, Pattern Recognition, Medical Instrumentation.