REAL-TIME DATABASE MANAGEMENT OF EVOKED POTENTIAL RECORDS

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INTRODUCTION

Somatosensory evoked potentials (SEPs) are signals recorded from the peripheral nervous system or the spinal cord in response to electrical stimuli applied at a peripheral site. The measurement of such signals can be used to test the integrity and functioning of the nervous system and to diagnose various neuromuscular disorders [1,2]. The detection and measurement of SEPs has been an ongoing area of research at the University of New Brunswick (UNB) for over 20 years. Over this time period, substantial amounts of data have been collected through the laboratory resources at the Institute of Biomedical Engineering (IBME). In the past this data collection has been conducted in an ***ad hoc*** fashion and with the passage of time has often been lost.

This paper describes a new approach to the management of SEP records that has now been implemented at UNB. A single dedicated machine has been set up as a data repository. Software has been written to catalog these data files into a SQL database. The novelty in this approach is that the data collection software automatically updates both the file repository and the database as the data is being collected in the laboratory. File transfer via FTP from the data acquisition machine to the remote repository is transparent to the investigator. Data retrieval for subsequent processing can be achieved through a JAVA based client from any machine with an Internet connection. This approach lends itself to the sharing of data between research centres, that may have the signal processing expertise but not the laboratory facilities of the IBME.

INSTRUMENTATION AT IBME

Since 2003, data collection for several projects has been standardized by employing custom written data acquisition software (*SEPacq*). This software provides a convenient means of conducting burst sampling with appropriate delays, time synchronized to the stimulation process. This has been implemented as a **MATLAB**[1] GUI that calls on the functions of the Data Acquisition Toolbox as required. By taking this approach, future changes in the ADC hardware, which is currently a simultaneous sample & hold, CIO-DAS 16-bit system, can be accommodated without the necessity to develop new custom code.

For SEP monitoring, the other main equipment requirement is a nerve stimulator. In the lab at IBME constant current stimulation is the preferred methodology although constant voltage stimulation is also available. The constant current stimulator is a programmable unit that is controlled from a PC type computer through a Windows GUI (*SEPstim*) [3]. The same computer is used to collect the data and provide stimulator control. This instrumentation setup is illustrated below in Figure 1.

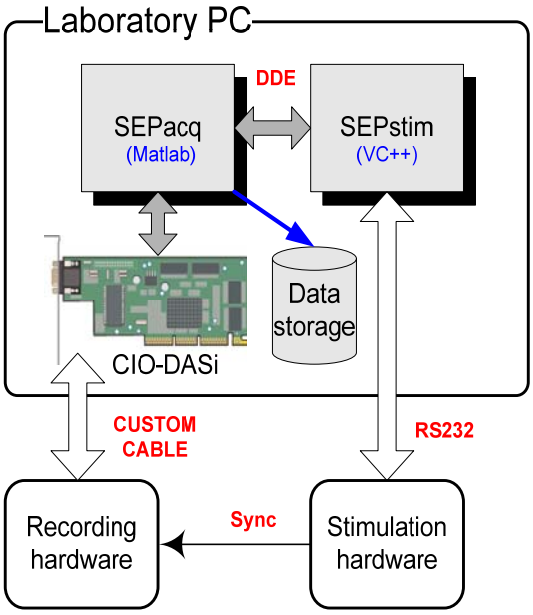

Figure 1: *SEP instrumentation at IBME*

A recent enhancement to this system is the linking of the two software programs through a dynamic data exchange (DDE) mechanism that allows ***SEPacq*** to interrogate ***SEPstim*** with regard to amplitude and timing information. In this way the stimulation details are automatically saved with the data without any intervention from the user.

SEP DATA REPOSITORY

Up until now, the SEP data collected at the IBME were stored as needed on numerous computers, mainly within the IBME, as the "personal property" of the current investigator – with informed consent. In some cases, these files remained on the data

[1] The MathWorks Inc., Natick, MA 01760, USA.

collection PC, a practice that has been discouraged at UNB. With the passage of time many of these records were lost or inadvertently deleted when cleaning up computers after a student or investigator has left.

Since 1980 the MIT-BIH Arrhythmia Database, has provided researchers with ECG data obtained from Holter recordings [4]. This has been invaluable in the development of various signal compression algorithms that are now used clinically to alleviate storage requirements. This database has also found use in the area of automatic arrhythmia detection and has become a 'Gold Standard' for algorithm evaluation purposes [5]. Initially distributed in CD-ROM format, it is now available on-line through ***PhysioNet***, which also provides links to several other databases of physiological signals.

This paper describes a similar approach taken at UNB, but applied to SEP waveforms. A dedicated computer has been set up as a data file repository. This is currently located in a faculty office (D. F. Lovely) in the Department of Electrical & Computer Engineering at UNB.

FTP SERVER

As MATLAB supports file transfer protocol (FTP) it was a relatively simple task to add this capability into the data acquisition program, ***SEPacq***. When a user saves a data file locally on the PC in the laboratory, a copy is automatically sent to the data repository via FTP. This action is transparent to the user.

To facilitate this data transfer a commercial FTP server was used on the target PC. The function of this server is two fold. Firstly, it is used for the upload of data files from the IBME lab to the data repository. Secondly, it provides the means for valid users to download copies of the SEP data for research purposes.

TitanFTP[2] was the commercial server chosen for this application. This server provides the administrator with an easy-to-use interface for controlling various options. Naturally, the transfer of patient data to and from the repository can only be allowed for valid users of the system. **TitanFTP** provides the mandatory security and access control features such as SSL for secure file transfers, and S/Key MD4 and MD5 password encryption. This software also allows the enabling or disabling of anonymous access, and the ability to permit or deny access based on IP address. Several other security measures have also been put into place, and are described later.

DATABASE MANAGEMENT

While the FTP server provides the necessary data file gateway to the repository, a SQL database server is required to provide the management functions for the indexing of the data files transferred from the IBME. Again a commercial product was used in this role. **MySQL**[3] is an open source database that is used in more than 10 million installations ranging from large corporations to specialized embedded applications on every continent in the world.

A typical SEP recording session produces multiple files each comprising multi-channel data with 256 – 4096 epochs. The corresponding MATLAB files are between 1 and 10Mbyte in size. Each file contains a structure that holds information regarding the experimental settings that include such details as location of recording and stimulation electrodes, mode and amplitude of stimulation and timing details.

After data collection in the laboratory at IBME, using ***SEPacq***, if the data is written to a local file and the data has been assigned a sharing attribute, a copy is automatically made in a temporary directory. A MATLAB script, ***SEPpop***, then extracts details of the experimental settings from the file copy and remotely populates the **MySQL** database on the data repository with this information. Once the information extracted from a data file has been uploaded to the **MySQL** database and confirmed, ***SEPacq*** transfers the copy of the data file to the data repository via FTP. If this is successful, then the temporary file is deleted from the IBME lab machine.

SEARCH & RETRIEVAL

Due to the anticipated growth in the number of files in the data repository, it was decided to provide some means of searching the database for a particular type of SEP record. This is a prime reason of incorporating SQL database management. It was decided to implement the search engine in JAVA so that remote search and retrieval over the Internet would be possible. ***SEPsearch*** acts as the remote search engine for the repository and provides the data retrieval function.

A modular approach was adopted in the coding of ***SEPsearch*** so that additional search terms could be added as required. Initially only FOUR search fields have been incorporated for prototype evaluation:

- Stimulation Site (*finger, popliteal, ankle…*)
- Stimulation Type (*constant current / voltage*)
- Recording Site (*forearm, spine, Erb's point…*)
- Recording Polarity (*bipolar/monopolar*)

[2] South River Technologies, Annapolis, MD, USA

[3] MySQL Inc., Cupertino, CA, USA

Once a username/password is confirmed, ***SEPsearch*** allows the user to connect to and search the **MySQL** database through a graphical user interface (GUI) as shown in Figure 2.

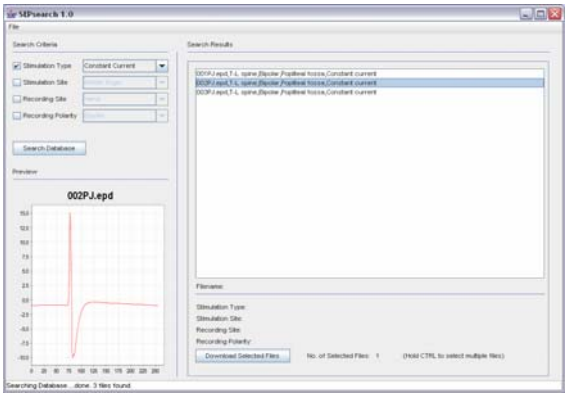

Figure 2: *JAVA based search GUI*

By way of check boxes and subsequent combo boxes, the user can refine the search to any logical combination of the four fields. Once the desired criterion is set by the user, ***SEPsearch*** uses SQL statements to interact with the database server and return matching results. ***SEPsearch*** displays the various file names that correspond to the matching criteria, and by a simply click, connects to the FTP server and downloads the appropriate data file. ***SEPsearch*** also shows a graphical preview of the selected data and can be used to conduct multiple downloads by highlighting more than one file.

DATA SECURITY

As with any collection of physiological information from human subjects, the issue of data security is a major issue. With this prototype system data security has been implemented at three specific levels, starting naturally at the subject level.

Informed consent

The first question to be asked in the formation of a SEP data repository is "*Do I have the permission of the subject to share the data collected?*" If this permission is given, then the next obvious question is "*With whom can I share this data?*" This has led to the adoption of four levels of sharing access possible:

- **Level 1:** limited to the investigator only
- **Level 2:** any machine at IBME
- **Level 3:** limited to machines at UNB
- **Level 4:** all registered users worldwide

This system has been integrated into the ***SEPacq*** software in which the user is prompted to obtain the relevant level sharing access during the informed consent process, as shown in Figure 3.

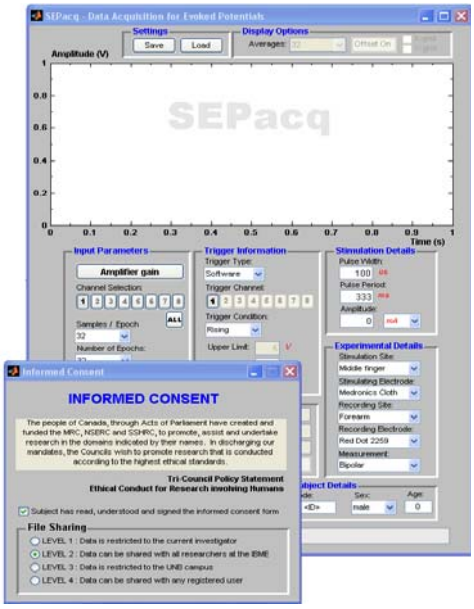

Figure 3: *Patient consent & security levels*

The sharing level access information becomes part of the data record and is used to limit access to the database. Level 1 security restricts the collected data files to the temporary storage on the laboratory machine and it is the responsibility of the researcher to transfer these files manually to an appropriate location. For Level 2 security and above, the data files are automatically transferred to the data repository.

Data acquisition - data repository link

The data acquisition computer is located in the laboratory at the IBME, and can only be accessed by the staff and students who have valid user accounts. These are managed by the system administrator who is a staff member of the IBME. The data repository machine is located in an office in the Department of Electrical & Computer Engineering at UNB. Direct access to this machine is limited to Dr. D. F. Lovely, who is the sole user of this machine. Both machines have static IP addresses.

Consequently, it was relatively simple to set up a security system whereby the data repository only accepts connections to the data from the appropriate data acquisition machine for file downloads and database population. Likewise the laboratory machine can only send files to the specified IP address of the data repository.

Registered users

The final layer of data security is the limitation of access to the data repository for searching and retrieval of files via ***SEPsearch***. This is achieved by a username/password combination for previously approved users. This aspect of the security protocol is handled by the **TitanFTP** server.

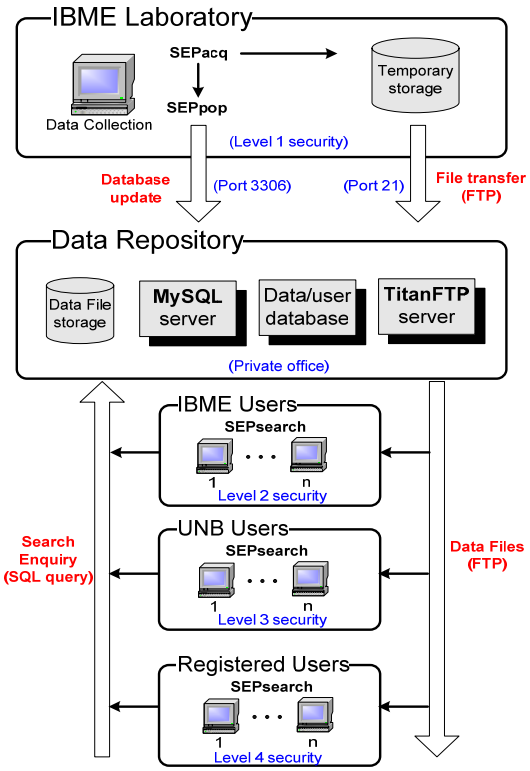

Figure 4: *Database access & security levels*

A user database is maintained at the data repository that associates username/password combinations with specific machine IP addresses. Depending on the IP of the machine on which the user is searching, comparisons are made with respect to the level of access granted by the subject. In this way only the appropriate data files are listed in the user GUI for selection to download.

EVALUATION

At the time of writing, the system is currently under evaluation. Tests are underway at the IBME to assess the data collection scheme and the remote updating of the SQL database. Dummy files are being added to provide a good basis for testing of the search capabilities. At present only 200 files are held in the data repository.

Evaluation of the JAVA search routine will include the timing of searches and file downloads. These naturally will be function of the number of files in the repository, the number of search terms and the size of the files. As mentioned earlier the prototype system has only four search terms, but this will be increased to evaluate the effect of providing more sophisticated search capabilities. It is also planned to investigate the effect of the number of concurrent users on the system performance and based on these findings a limit may have to be placed via the features of the **TitanFTP** server.

CONCLUSIONS

At present the system is working as designed. This software is adding to the infrastructure at IBME for SEP data collection, record management and analysis.

It is hoped that this approach will encourage inter-university collaboration especially those that have a strong background in signal processing research without the associated laboratory facilities.

Finally, this system has the potential application to other data sources, such as EMG signal processing, which the IBME has a worldwide reputation.

FUTURE WORK

During the development of the code, error handling has been employed throughout to provide system robustness. For example, if the FTP fails during uploading of the data to the repository, the temporary file is not deleted; this could occur if the data repository is off-line for any reason. It is planned to develop stand-alone code that will run on the IBME data collection computer to periodically check the temporary storage directory for data files and automatically transfer these when the data repository comes back on-line. This routine would be written in C++ and would be incorporated into the machine start-up routine. In this way, if the data collection computer is powered down, before all data transfers have taken place, transfers would be automatically scheduled on restart.

A second future area for development would be a WEB based registration process for users of the system. It is also planned to investigate whether this system could become part of ***PhysioNet*** once the system has been fully tested and evaluated over a period of time.

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