

Development of generic software for analysis, archiving & Internet dissemination of brain and systems physiological data.

DS Holder[#], RH Bayford^{+##}, J Fritschy[#], O Gilad[#], H Kaube[~] and CD Binnie^{*##}

Clinical Neurophysiology & Medical Physics, University College London [#]

School of Health and Social Sciences, Middlesex University ⁺

Clinical Neurophysiology, King's College Hospital, London ^{*}

Institute of Neurology, University College London [~]

Introduction: Electroencephalogram (EEG) is a recording of the electrical activity of the brain, made from various different points on the surface of the head, which is used by clinicians to diagnose various neurological disorders. The data can be as many as 128 channels but normally 20 channels are used and recordings typically last for 30 to 60 minutes of time domain information, with a bandwidth between 0.1 to 150Hz, which is displayed digitally on a computer screen.

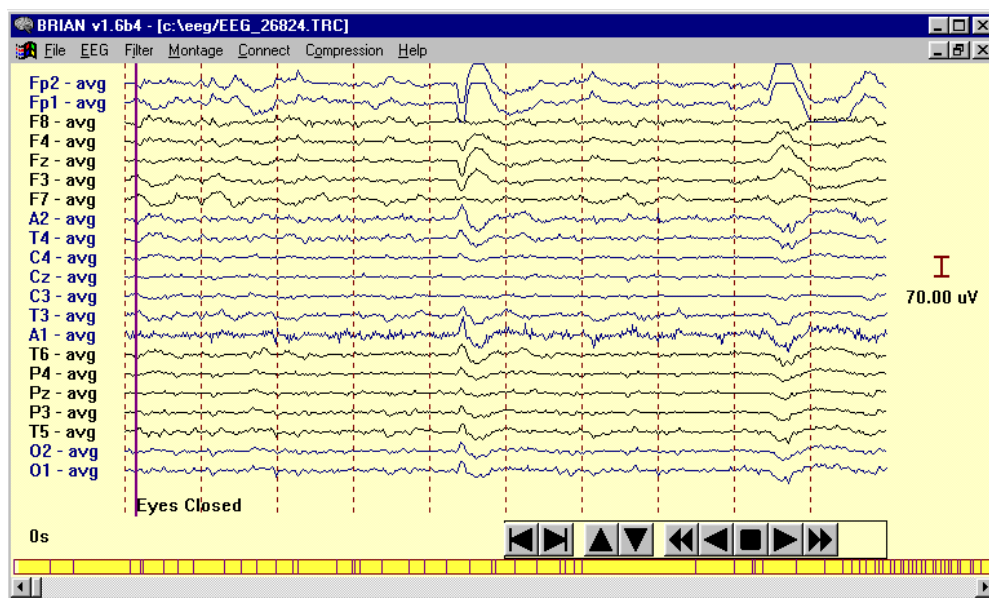


Figure 1: Example of an EEG trace visualized on a PC screen.

A common scale is: X-axis – 10 seconds by screen, Y-axis - 70 micro-volts for each of the brain potentials.

Until ten years ago or so, EEGs were recorded with analogue amplifiers and printed out on paper. Over the past decade, the data has been digitised and is reviewed on PCs and their monitors (Figure 1). The data in an EEG is complex and it is not possible to compress it in a non-lossy way by more than a factor of two. Until recently, therefore, EEGs were reviewed at standalone computers, or, at best, over a high-speed network, because the data was too great to send over an Internet link. This caused considerable inconvenience, as doctors specialised in EEG reporting are scarce, and there is often the need for urgent or routine reporting of records collected at remote hospitals.

The purpose of this project was the development of a tool to view and analyse this data at remote locations using the Grid infrastructure.

Method: Over the past four years, we have set out to develop software, which would enable EEGs to be transmitted for routine review over a telephone link [1]. However, the growth of this system requires a new layer of complexity in terms of data management considerations and the post processing of the EEG record to improve the diagnostic and research potential. It is vital that the right infrastructure was put in place to exploit the data set fully and access

sufficient computation power to perform post processing. The evolution of the Grid technologies, such as Globus [2] has concentrated on provision of protocols, services and tools for creating coordinated, transparent and sure globally accessible computational systems. The delivery of the low-level infrastructure is essential but does not aid the clinical user in the creation of application that use all the Grid has to offer. Some systems are now emerging that exploits the Grid's potential [3] and it is our aim to offer a tool, which can evolve with the Grids development.

We have developed a new system architecture, which is illustrated in (Figure 2) which exploits the Grid infrastructure. The underlying infrastructure will support the interconnectivity of the distributed system for data mining and post processing to extend the user base. Current research into fundamental Grid technologies does not provided a simple architecture for clinical application. This project has developed a basic system architecture for review and analysis of EEG records, which provides a low level entry of the clinical user. The clinical user can evaluate and reanalyse the patient record using a simple browser.

Progress: We are currently developing a library of EEG records with documentation; this is linked to the Website of the British Society of Clinical Neurophysiology (www.bscn.org.uk). The library is distributed over a range of location as illustrated in figure 1, with the long-term aim of integrating a number of data NHS clinical record to allow data mining. Access to the EEG records has two routes - the first is a version to the original Brian client and alternately a collaboration with a commercial EEG company, has given us the option of providing a commercial viewer. The web site also promotes a discussion group on specific EEG records as an education tool. The result of these discussions are integrated into the clinical record.

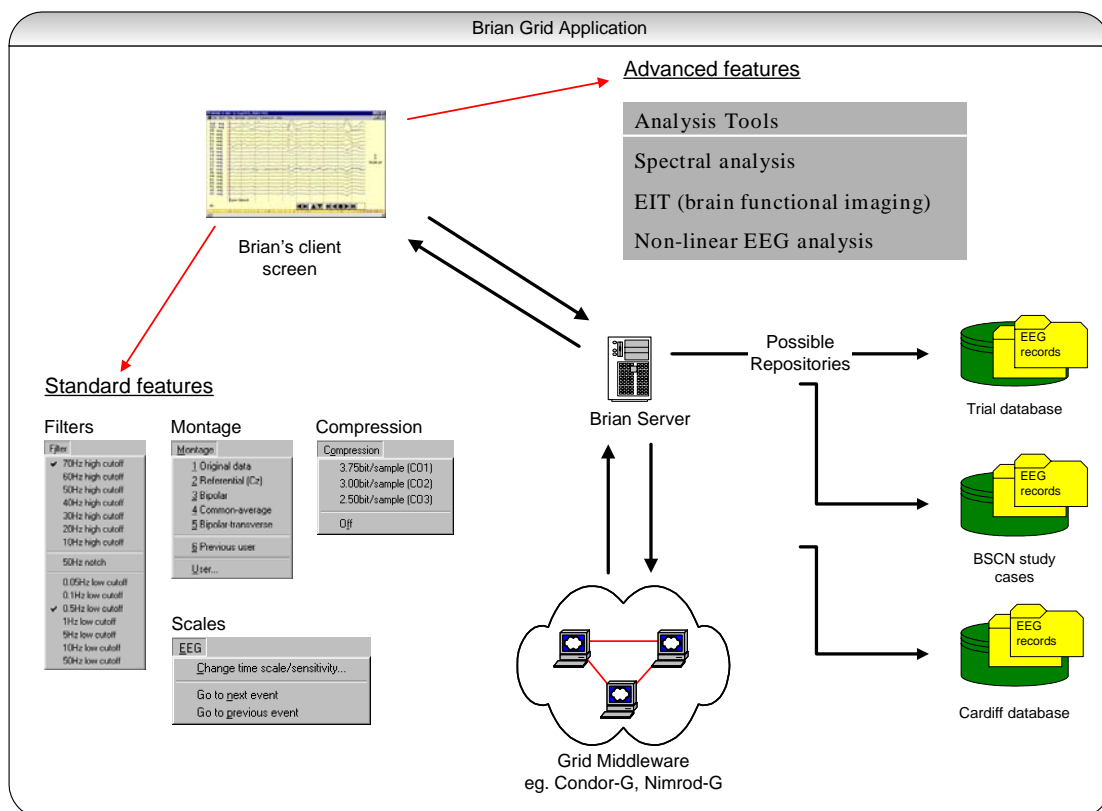


Figure 2: Brian Grid system architecture

We have also been exploring the use of this infrastructure for imaging brain function with the novel method of Electrical Impedance Tomography (EIT). Our group has developed novel non-linear reconstruction algorithms, which are computationally intensive and currently

would take a month to reconstruct each image on a standalone PC. The power of the Grid is ideal for speeding this up so it can be clinically useful in imaging conditions like stroke and epilepsy (Figure 3), where images need to be reconstructed in minutes. A number of new non-linear post-processing techniques have been developed to link with the Grid Condor utility [4].

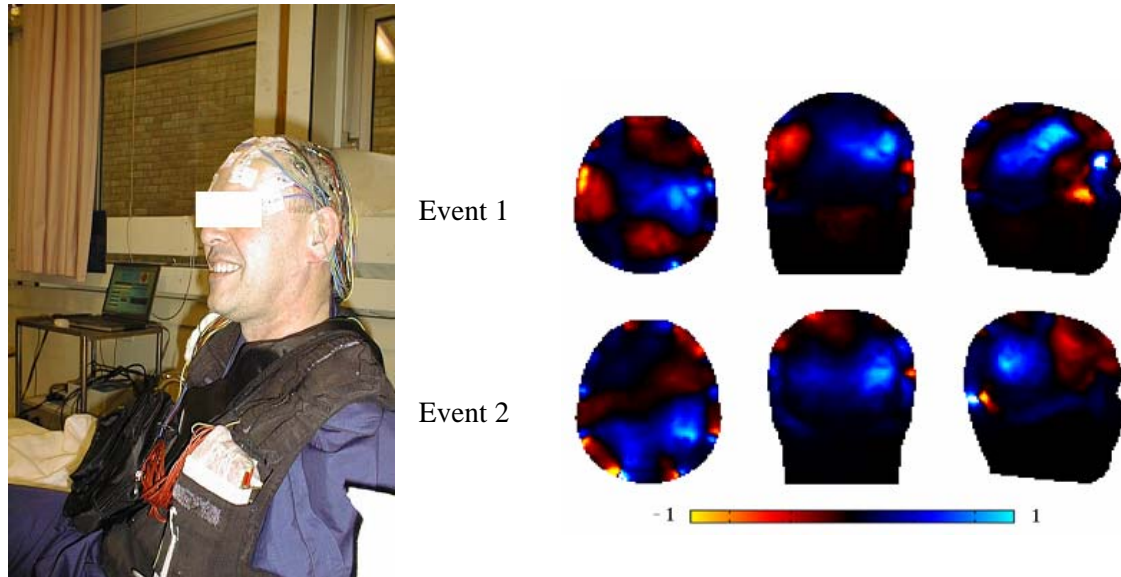


Figure 3: Example of using EIT reconstruction algorithms to detect epilepsy seizures. The photograph shows a patient during the EIT and EEG simultaneous study. The figures on the right side show images from the three axes (axial, coronal and sagittal) for two events with clearly identifiable impedance changes.

These include a Variable-Metric and Conjugate-Gradients, both with Brent line search and with regularized search direction for non-linear reconstruction [5].

An example of the information, which can be obtained with EIT, is presented in Figure 3 [6] [7]. This shows conductivity increases due to epileptic seizure, which was present in the EIT image 20s before the EEG trace indicated this activity. The EEG and EIT data was collected simultaneously. This imaging method will provide an invaluable plug in for advance analysis of neurological data, which would only be possible by exploitation of the computational resources of the Grid. We are also planning to investigate the use of other non-linear methods to determine treatment responders in migraine and brain function.

Our goal is to develop an advanced infrastructure that will support a secure clinical data management and analysis tool for neurologist.

References:

- [1] Holder D, Cameron J and Binnie C. Tele-EEG in epilepsy: review and initial experience with software to enable EEG review over a telephone link *Seizure* 12, 85-91.2003.
- [2] I Foster and C Kesselman. Globus: a metacomputing infrastructure toolkit. *Int. J. Supercomputer Apl.* 11 (2), 115-128.
- [3] Ian Foster et al. The Physiology of the Grid. An Open Grid Services Architecture for Distributed Systems Integration. <http://www.globus.org/research/papers/ogsa.pdf>
- [4] *Condor-G: A Computation Management Agent for Multi-Institutional Grids.* J. Frey, T. Tannenbaum, M. Livny, I. Foster, S. Tuecke. 2002. <http://www.cs.wisc.edu/condor/doc/condorg-hpdc10.pdf>
- [5] Beyond the linear domain - The way forward in MFEIT image reconstruction of the human head L Horesh^{a1}, R H Bayford^{a, b}, R J Yerworth^a, A Tizzard^b, G M Ahadzi^b and D S Holder^a

¹ r.bayford@ucl.ac.uk; tel 442073879300x(3045); fax 442073879302;
<http://madeira.physiol.ucl.ac.uk/midx-group/>

- [6] Andrew P. Bagshaw et al. Neuroimage 20 (2003) 752-764. Electrical impedance Tomography of human brain function using reconstruction algorithms based on the finite element method.
- [7] L. Fabrizi, M. Sparkes, D.S. Holder, R. Yerworth, C.D. Binnie, R. Bayford. Electrical Impedance Tomography during epileptic seizures: Preliminary Clinical studies. Proceedings of the XII international conference on Electrical bioimpedance and Electrical Impedance Tomography.