IJBEM
Vol. 7, No. 2, 2005

BrainStorm Electromagnetic Imaging Software

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Abstract – **BrainStorm is a collaborative project to build a software suite for EEG and MEG data visualization, modeling, and source imaging, with integration of MRI and fMRI information. BrainStorm is a Matlab-based toolbox distributed under the GNU public licensing and runs on any platform supporting Matlab. Forward models include multi-concentric spheres, fast EEG multisphere solutions, overlapping spheres, boundary elements with constant or linear approximations, collocation or Galerkin weighting, and optional isolated skull approach. Finite element methods and an atlas-based generic head model for use with EEG data have recently been added. Inverse methods include least-squares, RAP-MUSIC, LCMV, variations of regularized weighted minimum norms, and statistical testing for regions of statistically significant activity. Results can be viewed as locations in MRI slices or as 3-D renderings onto cortical surfaces. The data format architecture is well-documented to allow the advanced user access to any point in the workflow. The software, documents, and publications may be found at http://neuroimage.usc.edu/brainstorm.**

Keywords – **electroencephalography, forward modeling, inverse modeling, magnetoencephalography, software development**

I. Introduction

A multitude of approaches to the MEG and EEG source imaging problem have been reported over the past two decades [1]. Evaluation and adoption of these approaches by the neuroscience community is limited by three main factors: i) methodology oriented publications on these papers rarely include task-based evaluation; ii) computer codes for most of these techniques are not available to the neuroscience community; iii) commercial software is often expensive and has a closed architecture which makes comparison and extension of these methods difficult. MEG and EEG source localization draws on a wide range of signal processing techniques including digital filtering, three-dimensional image analysis, array signal processing, statistical analysis, image modeling and reconstruction, blind source separation, time-frequency analysis, and phase synchrony and coherence estimation. This range of techniques for MEG and EEG analysis cannot currently be found in a single or even multiple compatible software packages.

BrainStorm was developed in an attempt to address these issues. Our goal was to distribute software to the research community containing implementations of methods that were fully described and evaluated in the open literature and in a form that they could be readily used and evaluated by other researchers. Secondary objectives included graphical user interfacing, integration of multiple modalities (e.g. anatomical and functional MRI); and visualization of time series, surface and volume data. Using MATLAB as a programming language, we were able to rapidly develop code. Furthermore, MATLAB also makes our code compatible with other open Matlab tools including SPM for statistical and volumetric analysis (http://www.fil.ion.ucl.ac.uk/spm/) and EEGlab for ICA analysis (http://sccn.ucsd.edu/eeglab/). Recently, we have also successfully collaborated with the University of Utah to make BrainStorm compatible with their-SCIRun/BioPSE software for bioelectrical field simulation and visualization (http://software.sci.utah.edu/ scirun.html).

II. Description

The first version of BrainStorm was released in 2000 and was downloaded by about 1,800 registered users. In Spring 2004, we issued a major new release of BrainStorm with tighter control of graphical interfaces and better integration of the workflow. Over 600 users have separately re-registered to download the new version. This release also included detailed help and tutorial pages, a user forum, and a site for logging and tracking bug fixes among developers. We formally adopted the GNU General Public License (GPL) in 2004 and provide the complete source code to all users. BrainStorm now comprises 39,211 lines of code and 32,852 lines of comments. The toolbox includes data preprocessing and selection tools, spherical and BEM forward models, an atlas based generic head model for EEG studies, inverse methods including dipole fitting, cortically constrained imaging and linearly constrained minimum variance beamforming, basic statistical analysis tools, and volume and surface alignment and visualization tools. For a toolbox of this size and complexity, we found it necessary to implement several custom development tools and procedures. We have automated routines to automatically catalog the functions, subfunctions, parameters, and graphical user controls and detail these in the header of

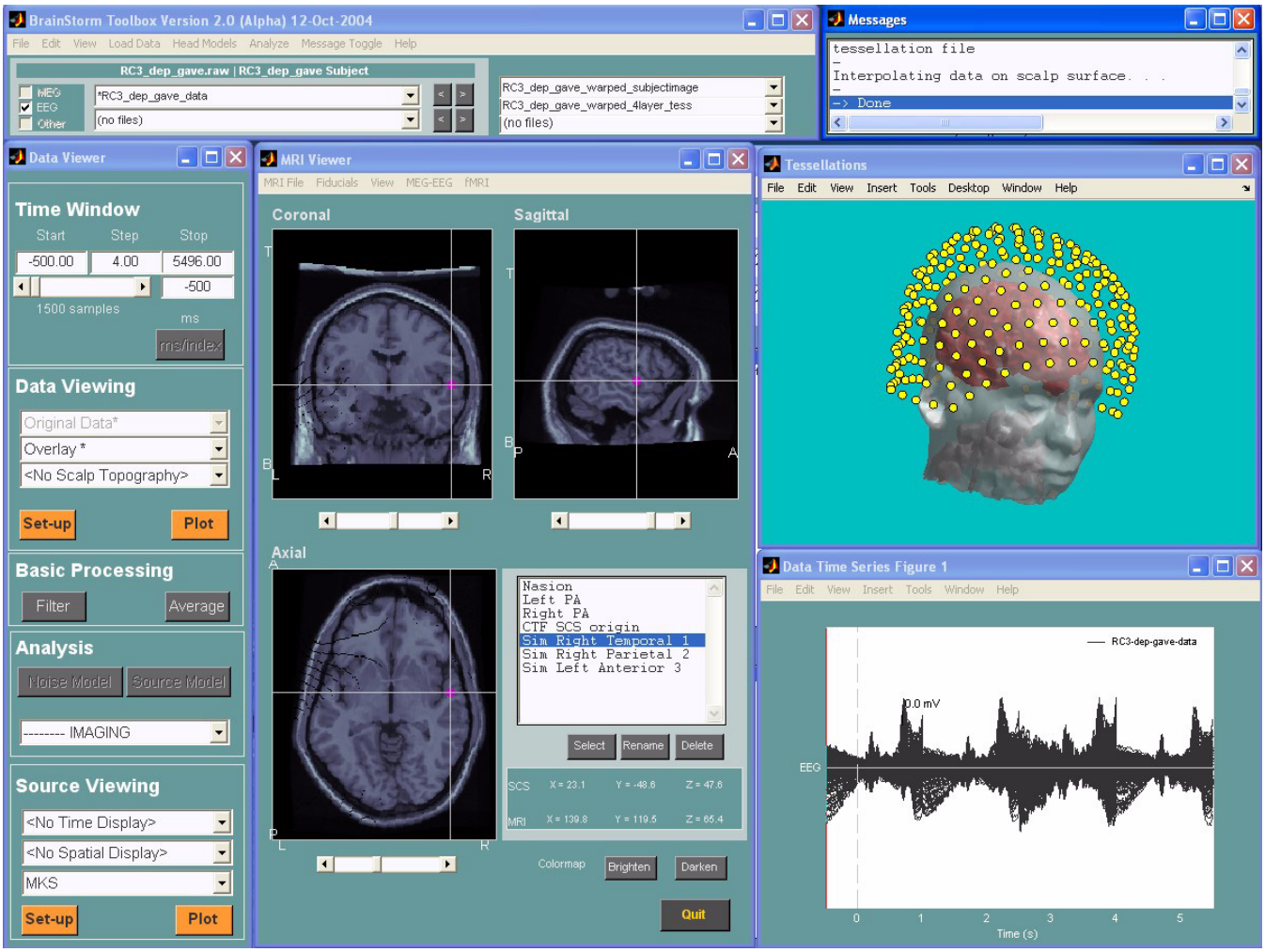

Fig. 1: Illustration of the BrainStorm interface.

each file. All software is developed using the configuration management tools Virtual Source Safe (VSS) and SourceGear's Source OffSite (SOS).

When distributed as "m-file" source code, a Mathworks Matlab license is necessary in order to execute BrainStorm, although no additional Matlab toolboxes are required. BrainStorm would be more attractive to many users if a Matlab license were not required (Note that "free" clones of Matlab such as "Scilab", "Octave", and "Rlab" are not 100% compatible for BrainStorm due to our extensive use of advanced rendering graphics). The Mathworks has compilers for generating stand-alone royalty-free applications. We have performed preliminary investigations of this compiler and have successfully generated a standalone version of a subset of BrainStorm which looks identical to the user but runs without needing Matlab installed on the user's computer.

The BrainStorm software, help pages, and many of the underlying journal articles can be obtained at http://neuroimage.usc.edu/brainstorm.

ACKNOWLEDGEMENT

This work was supported by the National Institute for Biomedical Imaging and Bioengineering under grants R01-EB002010 and R01-MH53213, by Los Alamos National Laboratory, operated by the University of California for the United States Department of Energy, under Contract W-7405-ENG-36 and by the Centre National de la Recherche Scientifique.

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