An Inverse EEG Problem Solving Environment and its Applications to EEG Source Localization

David Weinstein
Leonid Zhukov
Christopher Johnson

Scientific Computing and Imaging Institute
Department of Computer Science
University of Utah
Salt Lake City, UT 84112
dmw@cs.utah.edu

Introduction

BioPSE is a scientific programming environment that allows the interactive construction, debugging, and steering of large-scale scientific computations. BioPSE can be envisioned as a "computational workbench," in which a scientist can design and modify simulations interactively via a dataflow programming model. As opposed to the typical "off-line" simulation mode (in which the scientist manually sets input parameters, computes results, visualizes the results via a separate visualization package, and then starts again at the beginning), BIoPSE "closes the loop" and allows interactive steering of the design, computation, and visualization phases of a simulation. A snapshot of our source localization algorithm running within the BioPSE environment is shown in Fig. .

We demonstrate the application of BioPSE to the construction of an EEG cost field for FEM a realistic head model, and single dipole source localization using the downhill simplex method.

Model

We constructed a realistic finite element head model from a volume MRI scan. The full mesh contained 320,000 elements and 60,000 nodes and six different conductivity regions. From this model, we selected 64 electrode recording sites at appropriate scalp surface nodes. We then simulated a focal temporal seizure by placing a dipole source in that region of our finite element model and running a forward simulation. We stored the resulting potentials from the scalp electrode locations as the "measured" data which we will be trying to reconstruct and visualize with our system.

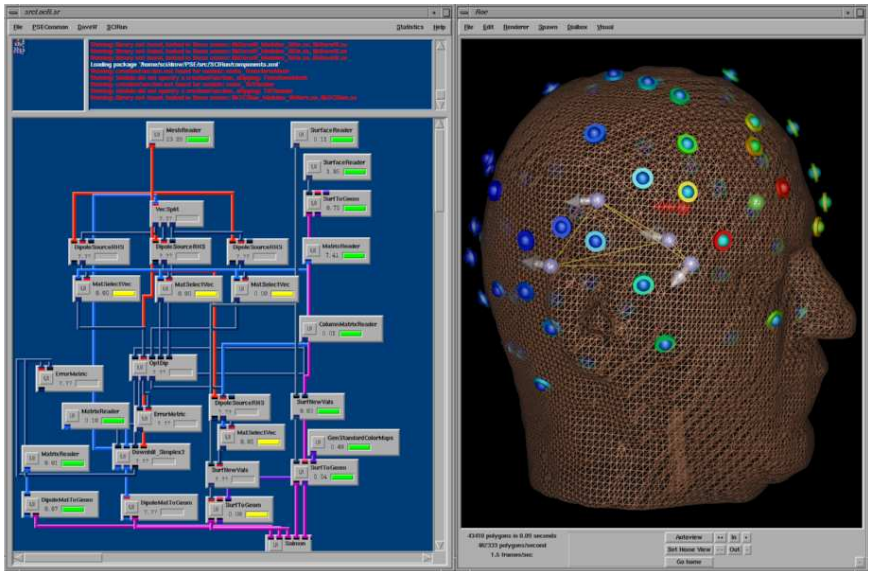

Figure 1: Source localization in BioPSE. On the left, the BioPSE dataflow network for source localization is running; on the right, the visualization window graphically displays the simplex search algorithm as it converges.

Cost-function Field Construction

A simple method for souce imaging involves evaluating a cost function everywhere in the volume and visualizing the results. The cost-function field is constructed as follows: position a dipole in every element one at a time; find the best magnitude and orientation for a source at that location (all locations within the same element are equivalent); compute the two-norm misfit between the forward solution due to that dipole, and the "measured" data. Visualizing this cost field allows us to easily find the global minima (optimal dipole position) as well as local minima and slope of the field.

Though very useful, this technique has not been previously used for realistic head models, as it has traditionally been very expensive to compute for real models. We dramatically reduce this expense by using the lead-field basis construction descibed in [1]. The lead-field basis construction works by exploiting the principle of reciprocity. Rather than computing the potentials at the electrodes due to a dipole in each element (requiring N=number of elements x 3 forward solutions), we only need to compute the electric field in the elements due to current sources at each elctrodes (requiring M=number of electrodes - 1 forward solutions). Each solution required on average 8 seconds of wall-clock time using 8 SGI MIPS R10000 processors, resulting in a total of 9 minutes to compute the lead-field basis. Using this basis, evaluting the cost-function at each element of the field required 320,000 evaluations and 2 hours of wall-clock time.

Source Localization

In order to localize a single dipole, we do not need to have the cost-function field in the entire volume. Rather, we can use a simple search technique such as downhill simplex and evaluate just those locations along a search path. For our model, this reduced the number of cost-function evaluations from 320,000 to 230, resulting in a source localization that can be achieved within a few seconds. However, we note that the downhill simplex search has the short-coming that it may converge on a local, rather than global minimum. Thus to be a reliable source localization technique, the search must be restarted multiple times from different initial configurations.

We have brought the user into the loop by enabling seed-point selection within the model. The user can seed specifically within physiologically plausible regions. This capability enables the algorithm to converge much more quickly, rather than repeatedly wandering through non-interesting regions.

Acknowledgments

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References

[1] L. Zhukov, D.M. Weinstein, and C.R. Johnson. Reciprocity basis for eeg source imaging. In *NeuroImage (suppl.)*, page 598, 2000.