NAVI-SciPort Solution: A Problem Solving Environment (PSE) for NIRS Data Analysis

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INTRODUCTION

Growing interest in NIRS imaging is creating an increasing demand for an integrated computing environment to explore the richness and complexity spatiotemporal measures of blood delivery to tissue. As with other complex systems, the computing environment should allow for the description, discovery, analysis and display of relevant phenomenology in ways that hold computational efficiency, flexible file management and convenient data access. In this report, we introduce a NAVI-SciPort solution shown in Figure 1 to deal with these issues.

NAVI (**N**ear-infrared **A**nalysis, **V**isualization and **I**maging) is a rich constellation of instrument performance checking, frequency filtering, image formation, feature extraction, statistical analysis, data viewing, data export, and file management tools for examinations of functional features of NIRS data. NAVI uses the MATLAB run-time component and is distributed as a stand alone program for Windows® or Linux (see Figures 1-5).

SciPort is an integrated web-based experimental and metadata management system for collaborative scientific research developed by Siemens Corporation Research (see Figures 1 and 4).

A NAVI-SciPort solution combines NAVI with a customized SciPort to provide users a comprehensive and fully interactive problem solving environment (PSE) with those features included in both software package (see figure 4).

The main key features of the PSE are discussed in the next sections.

MAIN FEATURES IN NAVI

File Management and Electronic Ledger

The DYNOT imager and its subsequent data processing by NAVI often generate a large number of files comprising multiple data types. To organize these, NAVI provides a file manager module, which employs a hierarchical data structure (see Figure 5a) linked to a project specific electronic ledger to organize, access, and save the multiple large-scale data types in a convenient and efficient manner.

The project-dependent electronic ledger keeps track of all facets of data generation, including instrument scanning parameters, FEM mesh details, and selected parameters used for data filtering, editing, feature extraction, *etc*. In short, all of the particulars needed to uniquely define the operations used for all steps of data processing are stored automatically in an organized and easily accessible format. In future versions of NAVI-SciPort, we plan to embed elements of the electronic ledger to provide for a searchable metadata data base.

Image Generator

Image generator is the most important portal in NAVI software package. It consists of project initialization, detector preprocessing and image reconstruction as well as data export.

The detector preprocessing module performs important data conditioning operations that precede: i) optional frequency filtering, ii) identification of useable channels, and iii) normalization of the raw-data time series

The Image Reconstruction module reconstructs the image time series from the normalized data produced by the preprocessing utility. The image-generation utility uses linear perturbation-based algorithms to reconstruct wavelength-dependent absorption and scattering coefficients. It also employs the pre-calculated FEM inverse model to speed up the performance. Subsequently, a second linear transformation converts the wavelength-based absorption coefficient images into time series of hemodynamic images (*i.e.*, oxy-Hb, deoxy-Hb, tissue blood volume, HbO2 saturation).

Data export module allows exporting NAVI-based detector and image data, to several different formats. The available formats make it possible for you to edit, view and analyze the exported data with other, commonly available software packages, such as AFNI, SPM, or GiD.

Anatomic FEM Model Library

NAVI provides a library of anatomic-based FEM models that is used for image reconstruction. Depending on the specified application (brain, breast, limb or others), the corresponding FEM model contains the pre-calculated inverse parameters that include a range of user selectable optode arrangements, associated with Jacobian operators, computed reference detector readings, coordinates of geometry-dependent FEM mesh, the coordinates of measurement conditions and the image of the FEM mesh.

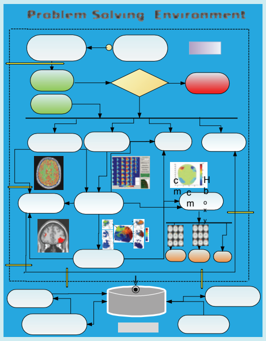

Figure 1. Diagram of the NAVI-SciPort Problem Soling Environment

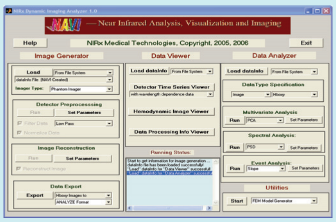

Figure 2. Main screen for NAVI software package

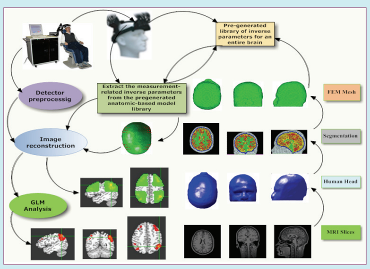

Figure 3. Diagram of DYNOT-based data analysis in NAVI

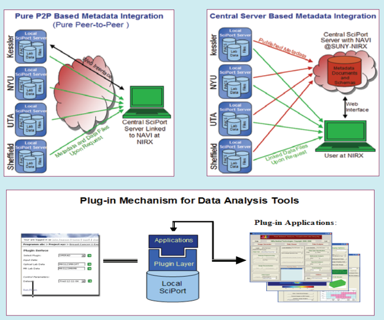

Figure 4. A Complete NAVI-SciPort Solution

As an example shown in Figure 3 for a brain neural activity study, the FEM model is created by the following steps: start from a standard MRI image template→ segment it to have a segmented brain model → generate the FEM mesh with possible measurement conditions → calculate its inverse parameters → save them in a FEM model library with a NAVI-based format.

FEM Model Generator

The FEM Model Generator module in the Utilities portal allows you to reconfigure an existing FEM model to match user defined source-detector geometry. Also, the module provides visualization utilities to explore important features associated with an existing or regenerated FEM model (for example, S-D configuration, mesh parameters, weight function coefficients, and reference detector readings (see Figure 5b).

Data Viewer

The data viewing portal provides for a broad range of viewing options, editing, and storage that can be applied to detector channel and 2D, 3D, volume rendered image data. Included are options for generation of movies, display of selected or complete channel/pixel time series, montage formats, and display of image data in an axial, coronal or sagittal view (see Figure 5c).

Data Analyzer

The data analysis portal provides feature extraction capabilities for blind or model driven signal separation (Principal Component Analysis, Molgedey-Schuster Analysis, Independent Component Analysis, General Linear Model), spectral analysis (Power Spectral Density, Cross Spectral Density, Coherence, Time Correlation, Wavelet, others), and event analysis (slope, time-delay, Area Under Curve). Exemplary screen shots employing the PCA, PSD and Slope analysis are shown in Figure 5d.

In addition, Figure 5e shows those graphical user interfaces in NAVI package used for autoregulatory analysis, which are reported in a second poster presented in the conference (R.L. Barbour *et al.*, Poster 219 M-AM)

INTEGRATION OF NAVI AND SCIPORT

Access to project specific searchable data bases and sharing of this information via the web with other groups is increasingly important in the conduct of scientific research. In collaboration with Siemens Corporate Research, Princeton, NJ, NIRx has developed an integrated computing environment that seamlessly merges all the capabilities of NAVI with their meta-data sharing engine called SciPort. Figure 4 shows the two different data sharing configurations currently available; pure peer-to-peer and a centralized server. Through SciPort, NAVI users can effortlessly gain access to DYNOT generated data sets world-wide. The searchable information space includes privacy protected subject demographics and other pertinent clinical findings, parameter specifications used to pre- and post-process DYNOT images, extracted image features and findings from statistical analysis.

CONCLUSIONS

We have developed a versatile problem solving environment that provides for the efficient and bulk processing of large scale NIRS data files. Available capabilities include: image generation, image enhancement, feature extraction and statistical parametric mapping, multiple display and data editing capabilities, automated file generation and, automated file generation, an electronic ledger and a meta-data-based file sharing capability

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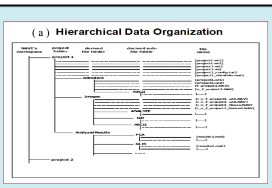
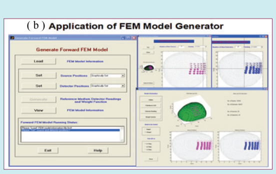
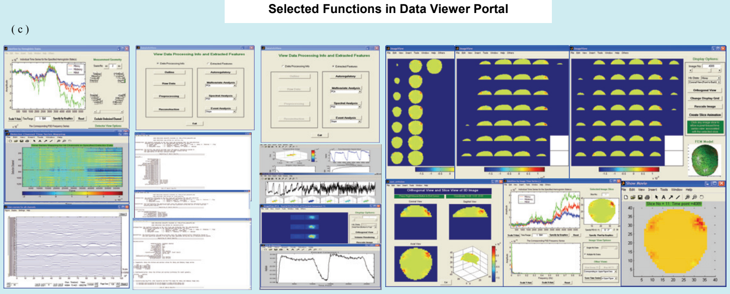
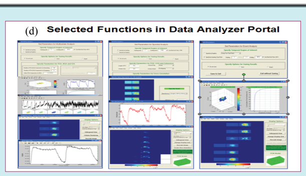




Selected Functions in Data Viewer Portal





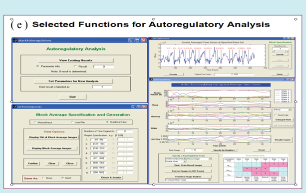


Figure 5. Examples of selected functions in NAVI