Web-interactive sharing of medical images and processing algorithms: the WISDM framework

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Introduction- There is growing consensus that sharing of medical imaging data and processing algorithms is a crucial step in reducing research costs and accelerating progress in our scientific understanding, for example in the area of neuroimaging[1,2,3]. Yet despite numerous benefits of data sharing between laboratories and across institutions and the efforts of various initiatives[1,4,5,6,7], the quantity of imaging data that has actually been made publicly available to the research community is only a tiny fraction of the total acquired[8]. Furthermore, efforts to share public data and processing algorithms presently focus on making archives of files available for download. However, numerous practical barriers exist to successful utilization of such archives, including the shear data size of raw imaging files (restricting convenience of both upload and download), operating system incompatibilities for running open source software, file format conversion issues, and incomplete documentation of data structure and organization.

Here we describe an alternate method for data and algorithm sharing that overcomes these barriers by providing interactive, on-line access through a universally accessible web browser interface. The web-interactive scientific data manager (WISDM) is an open source framework allowing imaging data stored on any internet-connected computer to be shared via web-browser either publicly or with a private group of collaborators, perhaps located at remote institutions. Users may interactively browse slices of raw, intermediate, and resulting image arrays (with four or more data dimensions) entirely within a web browser without the need to download large files or to install additional software (other than the browser itself). In addition, processing algorithms written in a variety of scripting languages (including MATLAB/Octave, C/C++, and Python) may be browsed on-line, and even edited and executed by authorized users.

Methods- The framework involves a central web server and a distributed collection of computing nodes where data storage and processing take place (see Fig. 1). Individual nodes maintain a perpetual TCP/IP connection to the central server, and therefore do not need to themselves run web server software. Nodes may, in fact, be located behind institutional firewalls. Data are accessed via a secure programming interface for retrieving portions of data files (e.g., individual slices), and all communication between the client (web browser) and processing node is filtered through the central web server enabling automated load balancing, optimized data caching, and secure permissions-based restricted access to private nodes.

Custom software for interacting with and processing data is developed at three distinct levels of WISDM. **First, custom user interfaces** for visualizing images and processing results may be programmed using standard web technologies such as JavaScript and HTML5 via the WISDM JavaScript API. Through this interface, developers may create customized views that access raw image data stored within the processing nodes.

Second, batch processing for operating on public or private imaging studies may be scripted using a transparent ECMAScript-compatible syntax. These scripts are online-viewable and execute on individual processing nodes. Unlike in traditional processing environments (such as MATLAB) where batch scripts may take hours to complete, WISDM scripts are be executed in a matter of seconds because low-level processes are not immediately run but are instead queued. Upon script execution, processes are assembled into an interconnected workflow, and are executed as soon as the necessary input files have been created and computing resources are available. This system has important advantages for remote, web-based analyses where multiple users may be logged in simultaneously and network connections may be lost during processing. Furthermore, provenance history for intermediate and result files is automatically tracked, avoiding redundant execution of individual processes.

The third level for custom WISDM development is programming **low-level processing procedures**. These procedures, which may be written in a variety of scripting languages including MATLAB/Octave, C/C++, and Python, and are included directly (via a macro syntax) into the batch processing scripts. In this way, all source code, even for low-level processing, is transparently accessible via the web browser. This has important advantages for verifiability and reproducibility of study results.

Results and Conclusion- The WISDM framework has been used at the author's institution for collaborative management, processing, and visualization of medical imaging data from a number of research studies in diverse areas such as high resolution structural imaging, dynamic cardiovascular imaging, and functional MRI of the human brain (Fig. 2). Each application requires a specialized web-based user interface for interacting with the complex data. The key advantage of this technology is that it allows multiple researchers to process and interact with a common pool of data from any operating system without the need to install additional software beyond a web browser.

References- [1] Van Horn et al., Philos Trans R Soc Lond B Biol Sci, 2001; [2] Yarkoni et al., Trends Cogn Sci, 2010; [3] Visscher et al., BMC Med, 2011; [4] Milham MP, Neuron, 2012; [5] Mennes et al., NeuroImage, 2013; [6] Glover, J Magn Reson Imaging, 2012; [7] Bjaalie et al., J Neurosci, 2007; [8] Poline et al., Front Neuroinform, 2012; **Acknowledgment:** NIH Grant K25-EB007646.

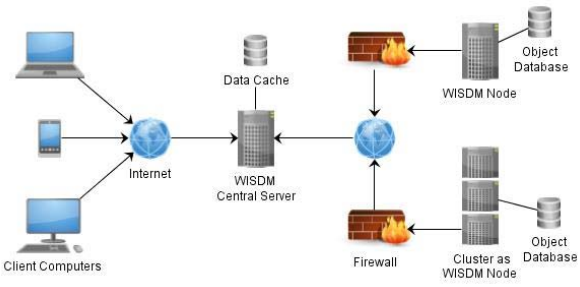

Figure 1. Users interact with data via the central WISDM server which interfaces with individual node computers. Data storage and processing take place on these nodes which do not need to be running a web server, and may reside behind institutional firewalls.

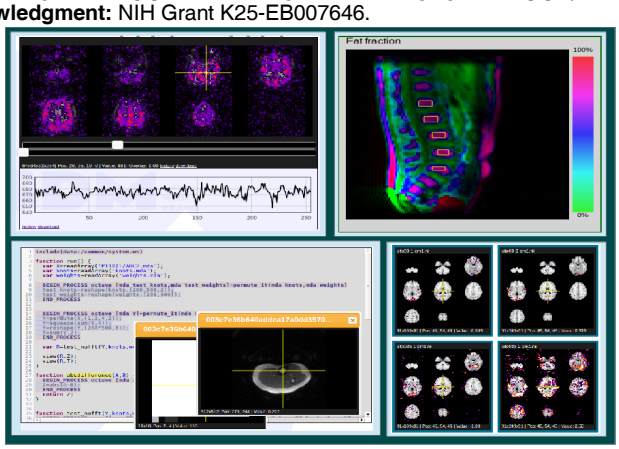

Figure 2. Example WISDM data analysis applications.