# BrainGPS: A Cloud-based Platform for Neuroimage Analysis and Neuroradiological Studies

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**Target audience**: Neuroimaging scientists and clinicians, particularly radiologists and neurologists.

**Purpose** MRI is a powerful tool for studying normal and diseased nervous systems. In the neuroimaging community, in the past decades, the technologies for image analysis tools have advanced considerably. Most notably, comprehensive brain segmentation methods based on multiple atlases have emerged as a promising technology, which identifies a structure of interest based on multiple teaching files (atlases). Deployment of this approach is, however, not straightforward. The algorithm requires a comprehensive set of atlases that covers a wide range of age and high-performance computational resources. In this presentation, we introduce internet-based Software as a service model (SaaS), a cloud computing technique to meet the requirements. Cloud computing outsources hosting and computing resources to infrastructure providers, frees end-users and service providers from investing on expensive, rapidly-to-be-outdated hardware. A comprehensive atlas set can be deployed, managed, and updated at the central server readily for all users. At the same time, Web 2.0 technologies make it possible to create interactive, graphic-rich web interface that resemble desktop applications but much more compatible and easier to update. BrainGPS (https://braingps.mricloud.org) is such a cloud solution.

**Results** Users of MriCloud can either create their own accounts or simply login using their Google account credentials. After logging in, several available services are listed: 1. MPRAGE pipeline; it accepts raw images without skull stripping and performs fully-automated, multi-atlas segmentation[1]. 286 structures or regions of interest (ROI) are defined at five different granularity levels[2] and their volumes are measured. Currently adult (20-90 years old) and pediatric (8-18 years old) atlases are available. The service accepts Analyze format data converted from DICOM files, after eliminating patients' identity information, using tools provided in the website. The submission webpage also includes several optional forms that users can fill in patient's electronic medical record (EMR) including demographics, clinical and radiological information. If the patient age is specified, the volume of each structure is compared with age-matched internal control and z-scores are calculated and visualized for data interpretation. 2. Diffusion Tensor Image (DTI) pipeline: it's a fully automated DTI data processing pipeline that includes 1) an image quality control routine by correcting mis-registration between diffusion weighted images (DWIs) caused by patient motion and distortion induced by eddy current[3] and 2) image corruption detection and rejection[4] 3) tensor calculation and 4) LDDMM based segmentation. 3. Users can check the status of their submitted jobs online and download results of finished jobs. 4. For the MPRAGE pipeline, users can also check the result directly online in a visualization page (Fig. 1). The page consists of axial, sagittal and coronal views of 2D slices and a 3D view of ROI surfaces. The images have been normalized in Montreal neurological institute (MNI) space and following radiology convention. Each of 2D views includes a layer of raw image and a superimposed, semi-transparent ROIs layer, which can be turned off by users. Each ROI is green-red color encoded by the z-score of its percentage volume. The 2D/3D images/surfaces can be zoomed, panned and rotated. The ROIs are sorted in tree structures. Based on ontology, there are two types of tree structures available. Both types of tree have granularity levels from the brain at highest level to the 286 segmented ROIs at the lowest level. When a ROI is clicked on, a menu about this ROI appears, which includes the links to the search results of the ROI's name as a keyword in major academic and public search engines and knowledge bases (e.g. PubMed, Google and Wikipedia). There is a plot of the volumes of the selected ROI together with all the data points from our internal control database used for z-score calculation (Fig. 2). Users can check their result against the population data, when they are interested in any subject, by clicking the data point, the visualization result of that subject will be shown in a new browser window.

**Methods** The system includes three groups of components (Fig. 3): 1. frontend user interface (UI) and Representational state transfer (RESTful) application programming interfaces (API). 2. Backend service controller handling the requests sent from interfaces and interacts with resources and 3. database, storage and computing resources. The webpage UI provides interfaces for user login, data submission, status checking, job managing, downloading and online visualization. The RESTful APIs are for other developers who want to connect their applications to our services. One API has been used in a plugin developed for submitting MPRAGE jobs from Osirix, a popular PACS workstation. The interfaces are running on http over Secured Socket Layer (SSL) for security purpose. The implement of webpage interface has extensively used jQuery JavaScript language library (http://jquery.com/). The implementation of 2D/3D display views has used the KineticsJS HTML5 canvas library (http://kineticjs.com) and the X3DOM library (http://www.x3dom.org). The metadata are transferred in EXtensible Markup Language (XML) and JavaScript Object Notation (JSON) formats between the webpage and server. The backend was written in php on Laravel (http://laravel.com/) web application framework. The database systems include MySQL (http://www.mysql.com/) for storing user accounts, job information, etc. For ROI volume data, MongoDB (http://www.mongodb.org/), a NoSQL database software has been used for its flexibility on handling complicatedly structured data. The computationally intensive data processing tasks are performed on several supercomputer clusters from the Institute for Computational Medicine of Johns Hopkins University and The National Science Foundation (NSF)'s Extreme Science and Engineering Discovery Environment (XSEDE) by paralleled, multi-threaded programs implemented in C++ and matlab.

**Conclusion** BrainGPS is a cloud solution for neuroimage computing and analysis. Future work includes performance improvement and links to pathology cases.

**Acknowledgement** NIH R43NS078917, R01NS084957, R01NS086888, XSEDE is supported by NSF ACI-1053575. **Reference** 1. Tang, X., et al., Bayesian Parameter Estimation and Segmentation in the Multi-Atlas Random Orbit Model, PLOS ONE, 2013; 8(6): e65591. 2. Djamanakova, A., et al., Tools for multiple granularity analysis of brain MRI data for individualized image analysis, Neuroimage, 2014; 101:168-76. 3. Penny W, et al., Statistical Parametric Mapping: The Analysis of Functional Brain Images, 1st Edition, Elsevier 2006. 4. Li Y., et al., Image Corruption Detection in Diffusion Tensor Imaging for Post-Processing and Real-Time Monitoring PLOS ONE 2013; 8(10): e49764.

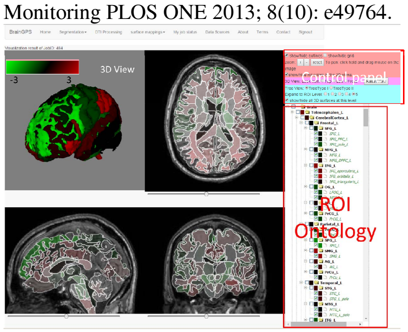


Fig. 1 Visualization page

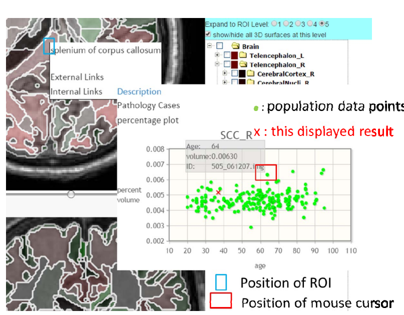


Fig. 2 Plot of population data of a ROI

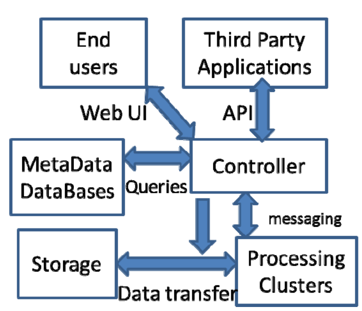


Fig. 3 System Architecture