

# Design and Implementation of GeoBrain Online Analysis System (GeOnAS)

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**Abstract.** GeOnAS is an extensible, scalable and powerful online geospatial analysis system based on Service Oriented Architecture (SOA), and is designed and implemented with the complementary technologies, Asynchronous JavaScript and XML (Ajax) and Web services, which greatly increase the interactive capabilities of graphical user interfaces and improve the user experience. It provides a highly interoperable way of accessing Open Geospatial Consortium (OGC) compliant web services for geospatial data discovery, retrieval, visualization and analysis, and leverages web service standards to enable service discovery, selection, negotiation and invocation for making more informed decisions.

**Keywords:** Web Service, Service Oriented Architecture, Asynchronous JavaScript and XML, Open Geospatial Consortium Specification, Online Analysis.

## 1 Introduction

Today many web-based geospatial applications are being built to help Geosciences researchers solve real-world problems. However, only a few could help scientists easily combine multiple, disparate geospatial datasets and provide powerful and advanced analysis functionality that goes beyond geospatial data visualizations.

A web service-oriented online geospatial analysis system, named GeOnAS (<http://geobrain.laits.gmu.edu:81/OnAS/>), has been implemented to make petabytes of data and information from NASA's Earth Observing System (EOS) and other earth science data providers easily accessible, and provide value-added geospatial service and modeling capabilities to geosciences community with a standard web browser and internet connection [1].

This paper describes design and implementation of GeOnAS. The remainder of this paper is organized as follows: section 2 reviews the previous and current progresses in this field; section 3 presents the system general architecture and data flow briefly; in section 4, each module of GeOnAS is described in details; finally, section 5 concludes and points to future work.

## 2 Overview

Geosciences researchers opt to use desktop geospatial software packages such as ArcInfo or PCI because they are more interactive and responsive than Web applications. But they

must purchase the commercial software, obtain geospatial datasets from various sources, preprocess these datasets, and analyze the datasets on their local machines [1].

Interactive Visualizer and Image Classifier for Satellites (IVICS), a free downloadable desktop visualization tool to facilitate selection of training samples from satellite images, has evolved into a general purpose visualization system that supports several common satellite and remote sensing data formats [2]. Multiple-Protocol Geospatial Client (MPGC), the predecessor of GeOnAS, provides an interoperable way of accessing OGC-compatible geospatial Web services for integrating and analyzing distributed heterogeneous Earth science data [3]. However, users must create the proper running environment for these tools on their computers.

Global Land Cover Facility at University of Maryland developed the Earth Science Data Interface for searching, browsing and downloading data [4], and Path/Row Search, Map Search and Product Search are provided to meet the requirements of the international scientific and educational communities [5]. However, geospatial data customization is not provided for user's convenience.

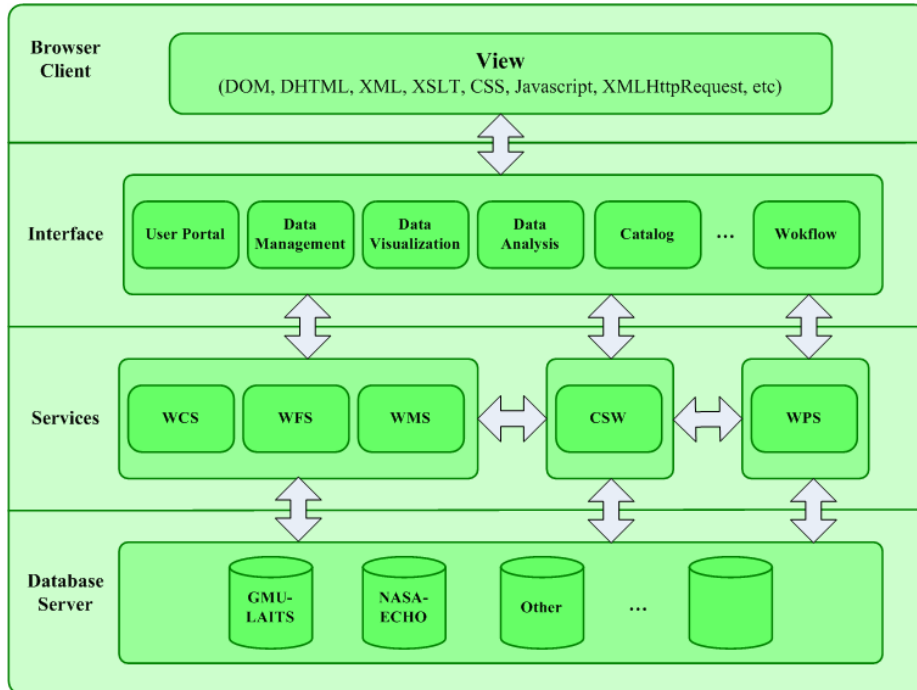
Earth Science Gateway (ESG) of NASA streamlines access to remote geospatial data, imagery, models, and visualizations through open, standard web protocols. By organizing detailed metadata about online resources into a flexible, searchable registry, ESG lets scientists, decision-makers, and others access a wide variety of observations and predictions of natural and human phenomena related to Earth Science [6]. ESG provides an easy, efficient and useful approach to integrate various geospatial systems and components through open interfaces [7]. Nevertheless, its capabilities for online geospatial analysis should be enriched.

Service Oriented Architecture (SOA) offers a fresh and flexible approach and an adaptive and responsive architecture for the development of web geospatial applications. Web services and Ajax enable developers to leverage web application in new extendable ways. These technologies are utilized in the implementation of GeOnAS.

### 3 Architecture

Figure 1 depicts the general architecture of GeOnAS. The fundamental design principle is to leverage distributed computational resources to support geospatial analysis and decision making [1].

The rich-browser client in the architecture is a web browser with Document Object Model (DOM), Dynamic HTML (DHTML), Extensible Markup Language (XML), Cascading Style Sheets (CSS), and JavaScript. This client allows processing of all presentation logics and presents all user functions via the standard web browser (i.e. Internet Explorer or Firefox). Intuitive graphical user interfaces, including pull down menus, trees list, toolbar, modal/modeless popup dialogs, and tabbed dialogs are implemented like those of desktop software bases on AJAX. Especially, user does not need to refresh the full page because XMLHttpRequest object in JavaScript is utilized to decouple user interactions in the browser from the browser requests to remote services [8].



**Fig. 1.** General Architecture

Interface includes the models of User Portal, Data Management, Data Visualization, Data Analysis, Catalog, Workflow, etc. User Portal enables user to store the portal state in a WMC file for future use by including a list of related data layers and processing services. Data management provides user with geospatial data retrieval via a network accessible point. Data Visualization provides a set of different rendering services to build their own preference. Catalog is targeted at metadata of geospatial data and processing services. Data Analysis offers the powerful processing services to perform advanced geospatial analysis. Workflow allows user to build a chain of services to perform the real world task [1]. These functions are implemented as Servlets and JavaServer Pages (JSP).

Services in the framework represent OGC specification compliant services. Along with Web Coverage Service (WCS)<sup>1</sup> developed by Center for Spatial Information Science and System (CSISS), George Mason University, the framework provides extensibility of other OGC standards, such as Catalogue Services for Web (CSW), Geographic Markup Language (GML), Web Map Context (WMC), Web Feature Service (WFS), Web Map Service (WMS), and Web Processing Service (WPS). Support for these standards enables GeOnAS to interoperate successfully and conveniently with other vendor web services across the globe.

<sup>1</sup> <http://data.laits.gmu.edu:8080/pli/www/wcs110.htm>

Database server represents repositories of geospatial data and information. GMU-LAITS and NASA ECHO (Earth Observing System Clearinghouse) could be accessed currently. The former one built and maintained by CSISS provides nearly 12 terabytes of raster data from NASA, USGS and other sources, including LandSat (ETM, TM, MSS), SRTM(30m resolution and 90m resolution), ASTER(L1B in GeoTIFF, L1B in HDF, L2 in HDF), BlueMarble (Generated from MODIS data), DMSP City Lights, EO1(Hyperion and ALI), WindSat(Soil Moisture Retrievals, Land Surface Temperature, Land Type, Observation Time), NetCDF(NOAA GOES data), and CEOP(MOD05, MOD11L2, MYD05, MYD11L2) for customization and analysis, and metadata tied to these datasets are registered in CSW server which also is implemented by CSISS. These datasets could be extracted, transformed and loaded through GeOnAS.

Figure 2 illustrates the typical data flow between the browser client and the application server in GeOnAS.

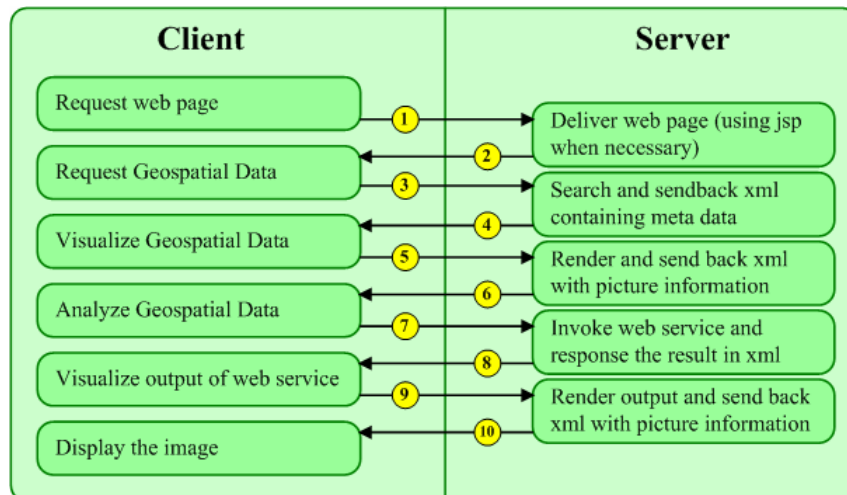


Fig. 2. Data Flow

## 4 Implementation

GeOnAS is deployed in an Apple G5 Cluster Server, which is composed of 1 Head Node, 4 Cluster Nodes, 3 Xserver RAIDs, 2Gbps Fiber Switch, 8-Port Gigabit Ethernet Switch, and other hardware [9]. The running environment could provide worldwide users with online heterogeneous geospatial data access and multi-source and powerful geospatial services at a high availability.

Now, GeOnAS includes the modules of Project Management, Data Manipulation, Map Operation and Display, Vector and Raster Data Analysis, Web Service Invocation and Auxiliary functions.

#### 4.1 Project Management

This module provides Create Project, Open Project, Save Project, Close Project, and Exit functions.

When creating a new project, user could specify the bounding box (by location name, inputting coordinates, or dragging box on the map) and coordinate reference system (CRS) of the project through an improved Google Map interface.

The project file could be saved as a WMC file to local disk for future use anywhere or data sharing, or as a Keyhole Markup Language (KML) file to integrate into Google Earth or Google Map. Figure 3 shows the false color composition output, which is shown in Figure 5 below, in Google Earth.

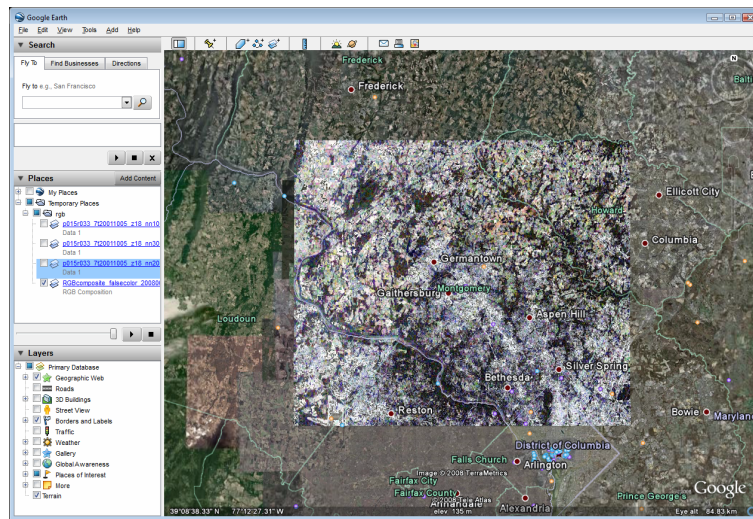


Fig. 3. False Color Composition Output Display in Google Earth

#### 4.2 Data Manipulation

This module contains Data Query, Data Selection and Customization, Data Adding and Removal, Data Rendering, Data Export, and so on.

User could specify query constraints, including temporal information, keywords, sensor name, platform name, instrument name etc, to perform query operations.

As shown in Figure 4, based on the query result set, the user interface of dataset selection provides preview, size, format, and description, etc. metadata information of geospatial dataset which could help user determine whether the datasets meet their requirements.

The selected datasets could be added with the customized resolution or width and height, and be rendered with the preferred palette in GeOnAS.

Datasets in the project could be exported to the local disk in multiple common formats (such as GeoTIFF, HDF) and specified projection coordinates via Data Export function, so user could make use of these exported file in other geospatial software.

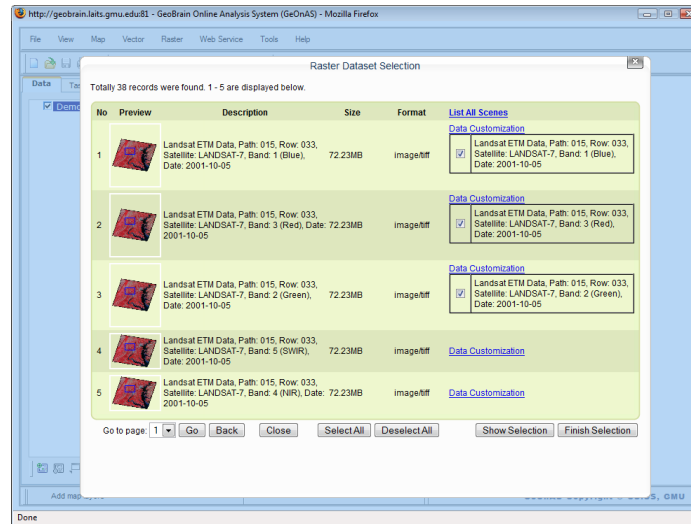


Fig. 4. Dataset Selection

### 4.3 Map Operation and Display

Zoom In/Out, Pan, Full Extent, Move Forward/Backward, Refresh, Overview and other basic map commands are provided to be similar to those of the common GIS and RS desktop software.

This module also allows user to show or hide map layer, control display order, export image, and set palette. For example, when a layer is selected and moved up or down in the layer tree, its display order will change on-the-fly.

### 4.4 Vector and Raster Data Analysis

Vector data analysis contains Feature Query, Feature Extraction, and Shortest Path function through invoking the corresponding web services registered in the CSISS CSW server.

Raster data analysis includes web NDVI, Image Algebra, Image Slice, Color Transformation (RGB2HIS, HIS2RGB), RGB Composition (True Color, False Color), RGB Extraction, Clipping, Image Patch, Image Mosaic, Classification (Supervised, Unsupervised) services.

These services wrap many of the associated functions of the open source GIS software Geographic Resources Analysis Support System (GRASS) [10], and are registered in CSISS CSW server so that they could be managed, discovered, and used effectively. The detailed description, including operations, input and output parameters, service location, Web Services Description Language (WSDL), etc. could be got at <http://geobrain.laits.gmu.edu:81/grassweb/manuals/index.html>. All these services are self contained and only loosely coupled with each other, so they could be composed into work flow to create a composite application.

Figure 5 illustrates the false color composition in GeOnAS.

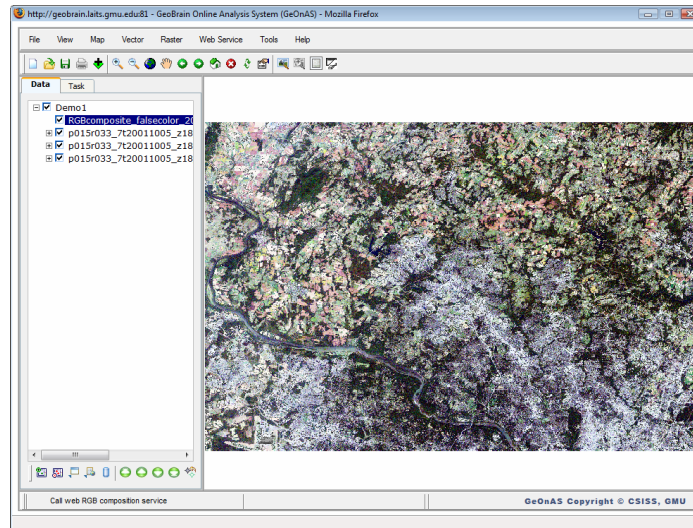


Fig. 5. False Color Composition

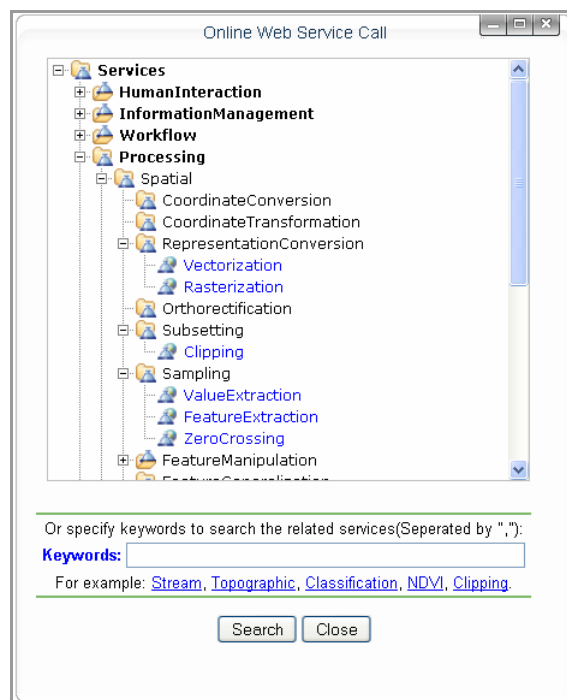
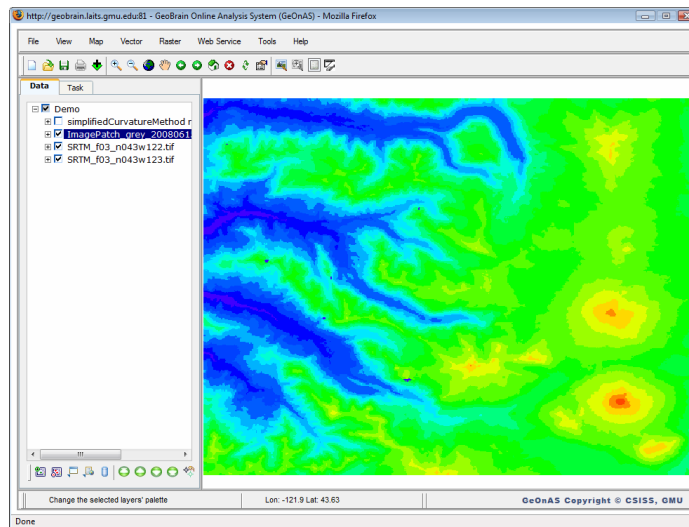


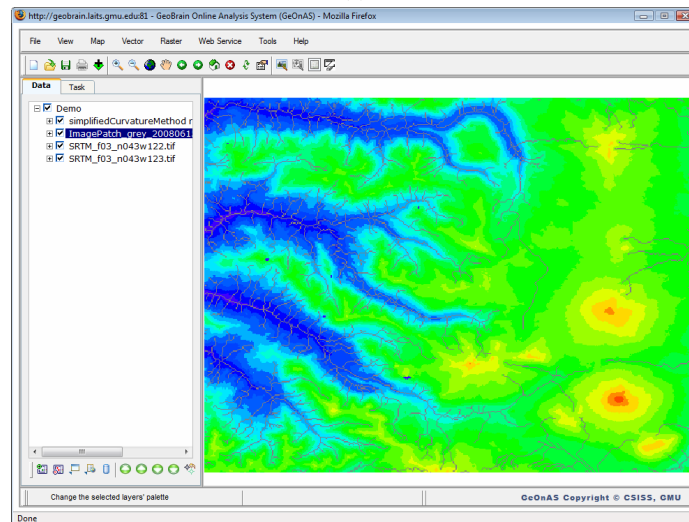
Fig. 6. Web Services Tree List

#### 4.5 Web Service Invocation

This module contains registered and unregistered web services invoking. One middleware, named Web Service Caller Client, has been developed and deployed to discover, select, and invoke either registered or unregistered web services asynchronously. The request and response messages between this client and web service are exchanged in Simple Object Access Protocol (SOAP) format. The output will be processed in this client and the appropriate results will be returned to the browser client.



(a)



(b)

**Fig. 7.** Stream Extraction Based on SRTM



Web services registered in CSISS CSW server are organized in the hierarchical structure derived from the semantic types of computation which are defined in ISO 19119:2005, as shown in Figure 6. User could input keywords or click the tree items to search the relevant services. The graphic user interface offers the operations, parameters, data types, binding information, and help for the specified service.

Figure 7 demonstrates the output of the registered stream extraction service which is performed on SRTM dataset.

Because of web services' significant overheads with respects to invocation, E-Mail notification is adopted to inform user the status of web service invocation if he close and save the current project.

#### 4.6 Auxiliary Functions

This module provides Background Scheme, Add to Favorites, Options, User Guide (in pdf and html format), Feedback, FAQ, About Dialog, etc. auxiliary functions.

### 5 Conclusions and Future Work

According to the statistics from Google Analytics, nearly 3,000 users from USA, Canada, China, Germany, Italy, UK, and other 21 countries and districts have visited GeOnAS since it was released to the education partners for public testing on October 2007. As seen in Fig. 8, the report gives a specific overview map of the site visitors distribution in USA from January 1, 2008 to June 13, 2008. Moreover, GeOnAS was demonstrated its cutting-edge capabilities in geospatial data publishing and accessing, information processing and retrieving, and knowledge building and sharing at AccessData 2008 Workshop<sup>2</sup>.

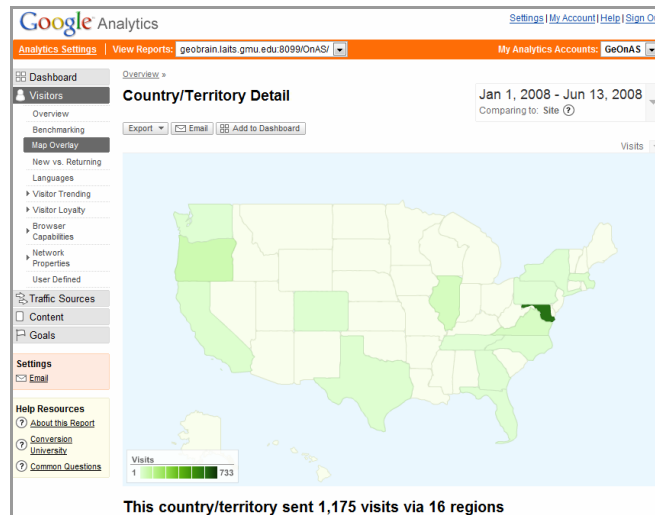


Fig. 8. Visitors Distribution Map

<sup>2</sup> <http://serc.carleton.edu/usingdata/accessdata/workshop08/team/geobrain.html>

Based on the suggestions and comments from users and project partners, we will enrich system functions, tune system performance to be faster and more responsive, and support the Opera and Safari browser in the near future. And the chained web-based services will be implemented to process geospatial datasets in user-defined ways and perform more complex analysis tasks at the end of this year.

In conclusion, GeOnAS not only enhances discovery, retrieval and integration of heterogeneous geospatial data and information, but it also employs distributed web geospatial services to solve a real world task in decision making. We consider that GeOnAS has great potentials to make impacts and differences to the geosciences researchers around the world; and it will help migrate these scientists from desktop GIS or RS software to on-line service-data offers.

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