

BUILDING AN ON-LINE GEOSPATIAL ANALYSIS SYSTEM WITH AJAX AND WEB SERVICES

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Abstract

Service Oriented Architecture (SOA), Web Services, Asynchronous JavaScript and XML (AJAX), and other new Web technologies have revolutionized the use of geospatial Web applications. The GeoBrain project has built a powerful online extensible and scalable geospatial analysis system based on SOA. This system utilizes Web Services and AJAX to increase the interactive capabilities of user interfaces and improve the user experience. It provides Geosciences community a highly interoperable way of accessing Open Geospatial Consortium (OGC) Web services for geospatial data discovery, retrieval, visualization and analysis. It also leverages Web service standards to enable geospatial services discovery, selection, negotiation and invocation to be used in making more informed decisions.

1. Introduction

With the emerging of AJAX based Web applications and the significant increase in Web services, more and more developers are enhancing the user experience and functionality of their Web geospatial applications by using these new technologies. And OGC Web services have enabled many organizations to publish and share their geospatial data and computing resources effectively through standard interfaces.

A completely Web-based, service-oriented, standard-compatible geospatial analysis system, named GeoBrain Online Analysis System (GeOnAS)¹, has been built to offer native web access to the terabytes of data and information from diverse sources, and to provide efficient geospatial Web services and better modeling capabilities for the Geosciences community to solve real world problems.

This paper describes mainly how to build GeOnAS with AJAX and Web services. Section 2 briefly reviews these technologies and their applications in geospatial information systems. Section 3 presents the system architecture and implementation in details. In section 4,

one example is given to illustrate the functionality of GeOnAS. Finally, section 5 summarizes the conclusions and directions for future work.

2. Overview

SOA offers an innovative and flexible approach and an adaptive and scalable architecture for the development of Web geospatial applications. This technology is designed to improve interoperability between diverse applications and support seamless business integration with a set of linked Web services [11]. These services should be self-contained, self-describing, reusable, and application-based units of work. Main GIS vendors and service companies have utilized SOA to provide integrated system service offerings, which make different geospatial Web applications from a variety of sources communicate and collaborate with each other.

The growing popularity of AJAX leads to the delivery of rich, appealing web applications, such as Google Maps, Gmail and Flickr, in a completely new and simple way. Currently, AJAX is supported by most browsers like Internet Explorer or Firefox. It consists of Document Object Model (DOM), Cascading Style Sheets (CSS), Dynamic HyperText Markup Language (DHTML), Extensible Markup Language (XML) and JavaScript. DOM is used to handle the returned document from server. DHTML and CSS are adopted to create the interactive and dynamic web pages. XML is for data manipulation and conversion. JavaScript is the client-side script for dynamically caching and displaying information that has been received using XML [12]. The adoption of AJAX brings user interface and functionality with rich, responsive, interactive and dynamic features, which are similar to those of traditional desktop applications, entirely inside the browser [7]. A couple of AJAX component GUI frameworks (Dojo Toolkit and Yahoo! User Interface Library) are freely available for download and use by public. Moreover, AJAX-enabled open source Web mapping frameworks like OpenLayers and MapBuilder are widely used by developers to build rich Web-based geographic applications.

¹ <http://geobrain.laits.gmu.edu:81/OnAS>

To make geospatial information and services from distributed sources accessible and useful with all kinds of applications, OGC² has led the development and implementation of a series of standards for geospatial contexts and services since its founding in 1994 [9]. These standards are actively supported by commercial software from ESRI, Leica Geosystems, Intergraph, etc. and open source software like MapServer, GeoServer, degree and more. And Atlas interface as metaphor for accessing Geospatial Data Infrastructure (Aim4GDI) [1], Multiple Protocol Geospatial Client (MPGC) [14], Earth Science Gateway (ESG) [2], etc. research projects have been implemented to access distributed geospatial data sources and perform specific geospatial analysis utilizing these OGC interoperability specifications [4].

The fundamental design principle of GeOnAS is to leverage large amounts of distributed geospatial data and computational resources to support advanced analysis and decision making [5]. So the development, adoption, and implementation of these mentioned technologies and standards provide a comprehensive capability to build GeOnAS.

3. Architecture and Implementation

GeOnAS aims to help Geosciences researchers discover, integrate, transform, visualize and analyze geospatial information dynamically from various sources using standard based Web services within SOA. As depicted in Figure 1, the overall architecture of GeOnAS has the following tiers: Client, Interface, Service, and Database.

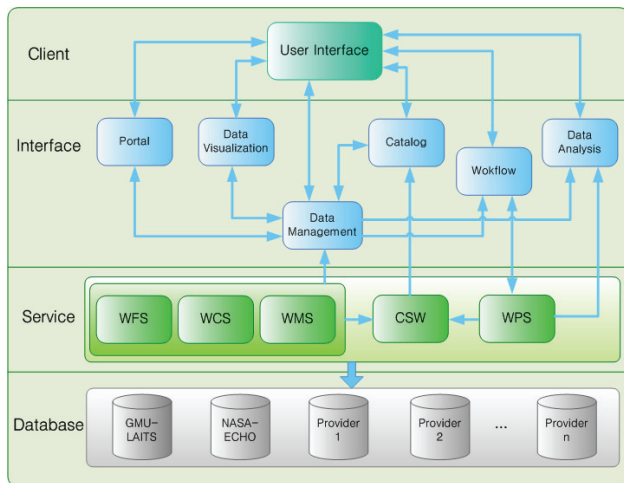


Figure 1. Overall Architecture

3.1. Client Tier

² www.opengeospatial.org/

Client Tier in the architecture is the user interaction layer. It allows processing of all presentation logic and user interaction flows in the common browsers [6]. The browser client of GeOnAS is an AJAX-based and rich browser based internet application, which users can access easily from any computer with an internet connection.

The *XMLHttpRequest* object based on HTTP in JavaScript is utilized to decouple user interactions from the browser requests to remote services asynchronously in the browser, so the entire web page will not be reloaded when a change is made [8]. Figure 2 illustrates the steps of the AJAX interactions between the Client Tier and the Interface Tier:

Step 1: A browser client event occurs;

Step 2: An *XMLHttpRequest* object is created, and a *callback()* function is configured;

Step 3: The *XMLHttpRequest* object makes a GET or PUT request;

Step 4: A servlet or JSP in Interface Tier processes the request and return an XML response;

Step 5: The *XMLHttpRequest* object calls the *callback* function, and this function processes the response;

Step 6: The HTML DOM is updated.

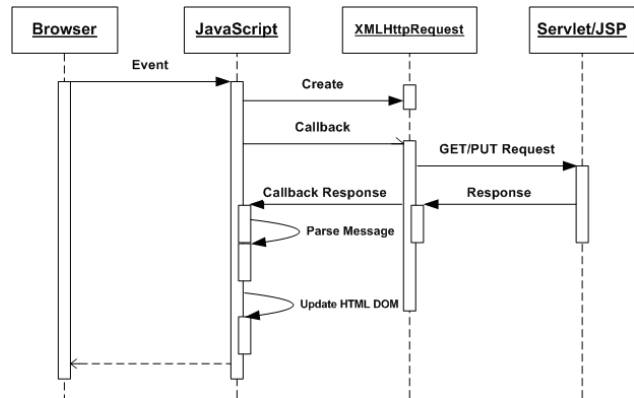


Figure 2. General AJAX Process

Following the above process, AJAX-enabled, friendly and interactive graphical user interface components, including pull down menus, tree lists, toolbars, modal and modeless dialog boxes, and tabbed forms (as seen in Figure 3), are implemented in the client to create a single-page geospatial Web application which looks and behaves more like traditional Windows applications. For example, the pull down menu with appearance parameters color, font, position, images, and others, loaded from an XML file for configuration, offers an easy, direct and flexible solution for web page navigation; the map layers tree allows users to show or hide the selected map layers and control display order.

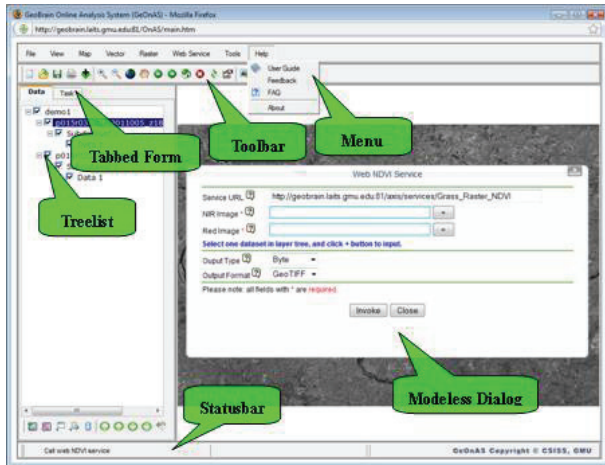


Figure 3. Graphic User Interface

3.2. Interface Tier

The functions of the Interface Tier contain User Portal, Data Management, Data Visualization, Data Analysis, Catalog, Workflow, which are implemented as Servlets or JavaServer Pages (JSP).

3.2.1 User Portal

User Portal has the following core functionalities: create and configure new project, save the project as an OGC-Compliant Web Map Context (WMC) file, and export the project as a Keyhole Markup Language (KML) file.

It provides a user-friendly interface with Google Map to specify the bounding box and the coordinate reference system (CRS) for new project. It also provides for storing the project information, like data layers and processing services, efficiently in a WMC file for future reuse or data exchanging and publishing. The composite project file created by users also can be exported as a KML file, which can be easily integrated into Google Earth or Google Map for data sharing, result visualization, comparison and validation.

3.2.2 Data Management

Data Management offers Data Query, Data Adding and Removal, Data Selection and Customization and Data Export.

Data queries are encoded in XML format, and users can specify one or more filter constraints (temporal information, keywords, collection, platform name, instrument name, catalog server, and archive center) to limit the number of geospatial datasets to be returned.

Where the total size of the result sets is large, the response will be returned in batches.

Standard OGC Web services access components are implemented to access to online geospatial data in varying formats and degrees of complexity.

Metadata information for the geospatial dataset (identifier, preview, size, format, description, etc.) is retrieved, using the query result parsed from the encoded XML stream to help users select those datasets that are pertinent to their specific research needs. Datasets can be added to the project by sending an *AddGeoDataRequest* request in XML format. Correspondingly, the dataset is removed when a *RemoveGeoDataRequest* request is processed successfully.

The datasets in the project also can be exported to the local machine in multiple common formats and specified projection coordinates, so users could consume them in other geospatial software.

3.2.3 Data Visualization

Data Visualization presents geospatial data in familiar formats, and provides users a set of different rendering services to choose formats of their own preference, so maps suitable for quantitative analysis can be rendered effectively.

It supports Zoom In/Out, Pan, Full Extent, Move Forward/Backward, Refresh, Area of Interest (AOI) and other basic map commands. Customized color palettes are provided to render data in GeOnAS.

3.2.4 Catalog

Catalog supports the discovery of and access to geospatial data and processing services for different metadata models.

Using the OGC Catalog Service-Web profile (CSW) specification, an eBRIM profile and the ISO 19115/19119 standards, Center for Spatial Information Science and Systems (CSISS) of George Mason University has developed the GMU-CSW server, which supports publication and discovery of both geospatial data and services in an OGC and ISO interoperable form [3].

Web processing services registered with GMU-CSW are organized in the hierarchical structure shown in Figure 4; this structure derives from the semantic types of computation that are defined in ISO 19119. Users can input keywords or select one among tree items to locate the relevant services registered in database. The graphic user interface offers the operations, parameters, data types, binding information, and help documents for the specified service.

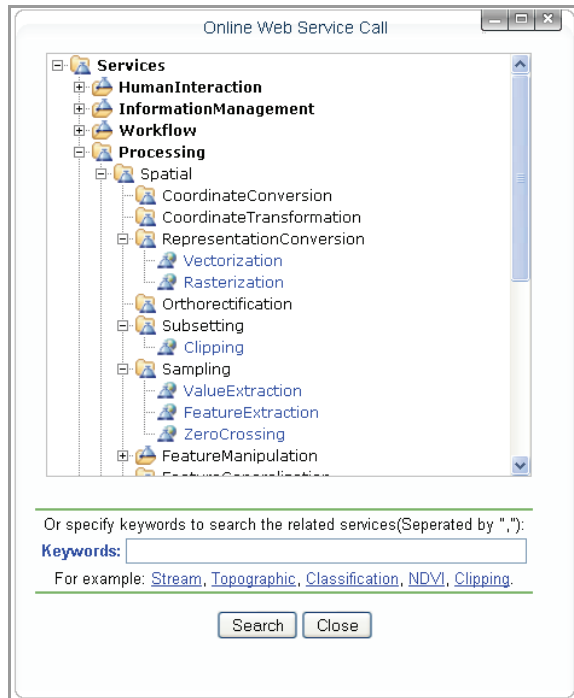


Figure 4. Web Services List

3.2.5 Data Analysis

Data Analysis provides a variety of geospatial analysis and geo-processing in the form of Web services for use.

A set of web services have been integrated and consumed in GeOnAS. These web services include Web raster data analysis services and Web vector data analysis services. The former ones consist of Web NDVI, Image Algebra, Image Slice, Image Stretch, Color Transformation, Color Composition, Color Extraction, Clipping, Image Patch, Image Mosaic, and Classification services. The latter ones contain Web Feature Query, Feature Extraction, and Shortest Path services. These services wrap many of the associated functions from the open source GIS software Geographic Resources Analysis Support System (GRASS), and are registered with the GMU-CSW server so that they can be managed, discovered, and used effectively. All these services are self-contained and only loosely coupled, so they can be composed into a workflow to create a composite application.

GeOnAS also provides one common interface to integrate other Web processing services distributed in different places seamlessly to perform the specialized analytical tasks.

One middleware package, *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 services are exchanged in Simple Object Access Protocol (SOAP) format. This middleware will process the output of web services and return the appropriate results to the browser client. Because geospatial Web services have significant overhead, there is E-Mail notification of the invocation status if the project has been closed.

3.2.6 Workflow

Workflow allows users to build a chain of services to perform customized scientific research tasks [13].

The composed workflow also can be registered in the CSW server as a service for invocation and next use. This enables GeOnAS to expand its solutions and services to the community additionally.

3.3. Service Tier

The Service Tier in the framework represents OGC specifications compliant services. Along with the Web Coverage Service (WCS), the framework provides extensibility of other OGC standards, including Catalogue Services-Web profile (CSW), Web Feature Service (WFS), Web Map Service (WMS), and Web Processing Service (WPS). For example, WMS delivers a static map of geographic information, WCS offers the delivery of rich raster data sources in formats such as GeoTIFF and DTED. Support for these specifications enables GeOnAS to interoperate with Web services from other vendors across the globe successfully and conveniently.

3.4. Database Tier

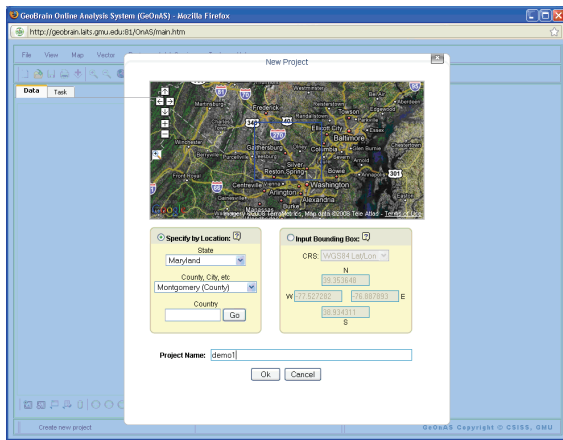
The Database Tier represents repositories of geospatial data and information. At present, it allows access to GMU-LAITS Server, NASA Earth Observing System Clearinghouse (ECHO) and other OGC-Compliant data services over the web. GMU-LAITS Server provides nearly 12 terabytes of geospatial data, including LandSat, SRTM, ASTER, BlueMarble, EO1, WindSat, NetCDF, and others from NASA, USGS and other sources. Metadata tied to these datasets are extracted and registered with the GMU- LAITS server. These datasets can be subset, transformed, loaded and analyzed through GeOnAS.

4. Examples

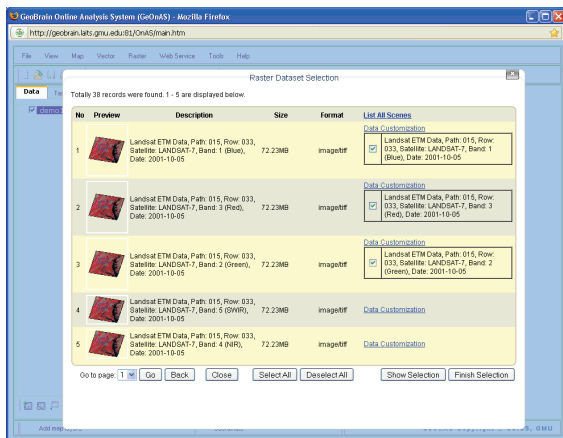
GeOnAS has been deployed in a cluster environment, which makes online heterogeneous geospatial data access and multi-source and powerful geospatial services readily available to users worldwide. The following example

demonstrates its capabilities for geospatial data accessing, information processing, and image processing.

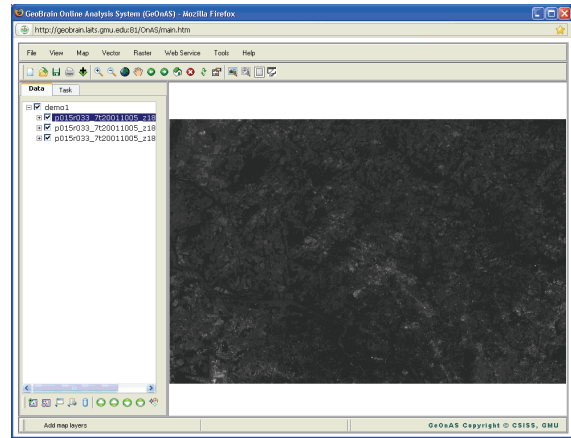
Color composition is the optical combination of images at different wavebands. It produces a single composite image closely approximating a false color photograph, which is easier to interpret than separate waveband images [10]. Figure 5 illustrates the false color composition process in GeOnAS, using LandSat ETM dataset for Montgomery County, Maryland as an example. Figure 5a shows new project creation using Google Map, including specifying bounding box, coordinate referencing system and project name. In the method illustrated by Figure 5b, metadata information retrieved from the server is used to select the waveband data. Figure 5c displays the subset of data which covers the example area. Figure 5d represents the output image of false color composition operation. Display of the exported KML file in Google Earth is shown in Figure 5e.



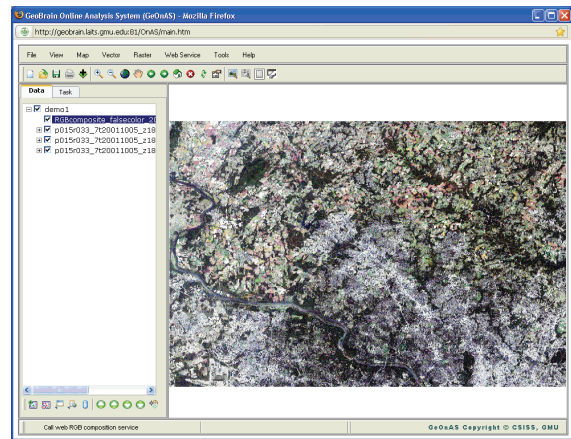
a.



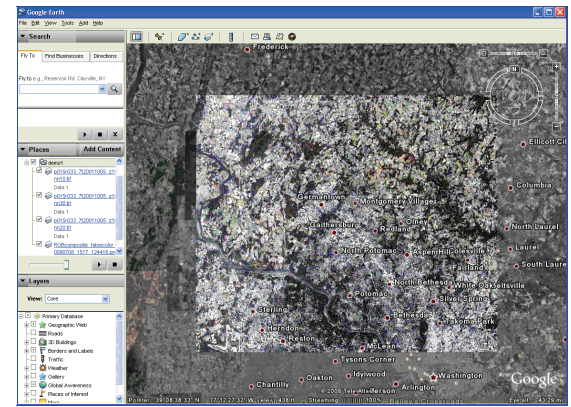
b.



c.



d.



e.

Figure 5. False Color Composition

5. Conclusions and Future Work

Since GeOnAS was released on August 2007, more than 3,500 users from around the world have visited it. Furthermore, project partners from multiple universities have explored uses of GeOnAS in their research and classroom teaching. Based on their comments and

feedbacks, the GeOnAS development team will enrich system functions with more intuitive interface, implement more web geospatial processing services, improve system stability and reliability, optimize system performance to be faster and more responsive and provide the support for more browsers.

In conclusion, GeOnAS offers the elusive online geospatial analysis user experience with nothing more than a web browser. It not only improves discovery, retrieval, and integration of geospatial data and information from multiple sources according to users' needs, but it also employs distributed Web geospatial services to perform specific tasks. GeOnAS has great potential to have an impact on the work of Geosciences researchers around the world, and will help them make full use of online data-rich and service-centric geospatial applications.

6. References

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