Utilization of Latest Geospatial Web Service Technologies for Remote Sensing Education Through GeoBrain System

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Abstract—GeoBrain **is a Web based geospatial information and knowledge system that adopts and implements the newly emerged geospatial Web service technologies. It provides innovative methods in remote sensing education to prepare students with world-view training and experiences, transfer spatial data and information technologies to the professional workforce and society at large, and meet the increasing needs for globalization for remote sensing education and research.**

Keywords-geospatial, data, information, knowledge, Web service, remote sensing, education technologies

I. Introduction

The economic globalization challenges remote sensing education with increasing needs for providing large globally-trained professional workforce to the society. The newly emerged geospatial Web service technologies can be utilized to meet the challenges in innovative ways, such as preparing students with world-view training and experiences and sharing spatial data, information, knowledge and computing resources world-wide. The geospatial Web service system has big advantages over the traditional non-service based system for reducing the difficulties of using remote sensing data [1]. However, due to the complexity of the Web service technologies and restriction on computing resources, it is difficult for current academic programs to take advantage of the latest geospatial Web service technologies.

A NASA funded project, entitled "NASA EOS Higher Education Alliance: Mobilization of NASA EOS Data and Information through Web Services and Knowledge Management Technologies for Higher Education and Research," provides insights and solutions to this problem. The project adopts latest geospatial Web service technologies to implement an open, distributed, interoperable, standard compliant, Web-service based, three-tier geospatial information system, called *GeoBrain*. The GeoBrain system is also a geospatial modeling and knowledge building system [2]. It aims to establish an on-line geospatial data-rich learning and research environment that enables students, faculty members, and researchers from institutes all over the world easily accessing, analyzing, and modeling with the huge amount of NASA Earth Observing System (EOS) data just like they possess those vast resources locally at their desktops. With the environment, classroom demonstration and training for students to deal with global climate and environment issues at any part of the world are possible in any classroom with the Internet connection. Data-intensive Earth science and remote sensing education can be truly realized through the environment.

This paper presents the cutting-edge technologies and infrastructure of *GeoBrain*. It discusses the foundation and major procedures to build GeoBrain learning and research environment, and most importantly, demonstrates how to use GeoBrain in classroom teaching and research and how the geospatial Web service technologies provided through the system can significantly enhance remote sensing and Earth science education.

II. GeoBrain Technologies

As mentioned above, the GeoBrain system adopts and implements latest geospatial Web service technologies. It complies with technology standards developed by national and international organizations, including the World Wide Web Consortium (W3C); the Open Geospatial Consortium, Inc. (OGC); International Organization for Standardization (ISO) TC 211; and the Federal Geographic Data Committee (FGDC). W3C is the major developer of technical standards for Web services applications, while OGC leads the development of geoprocessing and system interoperability implementation specifications compatible with standards set by ISO, FGDC, W3C and other organizations. W3C and OGC Web services standards and specifications are the foundation for implementing geospatial Web services in GeoBrain [3][4].

GeoBrain provides Web service technologies for facilitating web-based interoperability in major geospatial topics, including Data or Data Access; Metadata or Catalog Access; Maps or Visualization; Spatial Reference System; and other Geoprocessing Services [5]. These topics actually can be classified into two big categories: Data Access/ Visualization and Data Analysis. Web-based geospatial interoperability means the broad use of georeferenced data or information from multiple sources over the Internet, that is, the essence of the sharing. The following sections will discuss in some details about GeoBrain technologies for those categories.

A. Data Access/Visualization

GeoBrain offers **interoperable, personalized, on-demand** data access and visualization to petabytes of NASA EOS data. This capability is enabled by OGC standard-based Web

Coverage Service (WCS), Web Map Service (WMS), Web Coordinate Transformation Service (WCTS), Web Image Cutting Service (IMCS), and Catalog Service for Web (CSW) implemented in GeoBrain.

The OGC WCS specification supports the networked access to multi-dimensional and multi-temporal geospatial data as "coverage" [6]. The WCS servers in GeoBrain provide customized geospatial data products encoded in HDF-EOS, NITF and GeoTIFF formats to meet the requirements of client-side rendering, multi-source integration and analysis.

The OGC WMS specification supports the networked interchange of geospatial data as "map", a spatially referenced pictorial image [7]. The GeoBrain Map service provides the visualization of the data.

An OGC WCTS [8] service has been operated on GeoBrain for re-projecting a coverage encoded in HDF-EOS Grid from one map projection to another one.

IMCS in GeoBrain allows user to obtain data inside/outside the boundary specified by a state/county name or a series of coordinates.

The OGC CSW specification supports the registry and discovery of geospatial information resources [9]. It plays a "directory" role in the open, distributed Web service environment. Data and service providers register their capabilities using metadata, and users can then query the metadata to discover interesting information. The CSW server in GeoBrain allows users to discover distributed service and data through a very simple user interface.

The above services provided by GeoBrain enable users to obtain data in the form they want without worrying about where the data are located and how to pre-process the obtained data into the ready-to-use form (e.g., subset, resample, reformat, and reproject). The capability of interoperable, personalized, on-demand data access and services (IPODAS) is fully operational in GeoBrain.

B. Data Analysis

GeoBrain provides **on-line data analysis** capability so that a user can conduct Earth science or remote sensing projects without the need to have large computing facilities locally. This power of GeoBrain relies on the fast access to data at major data center through fast networks, the existence of high-performance computers, and most importantly, the availability of a large number of interoperable, web-based geospatial processing services capable of working on these data directly [10].

It is very time-consuming to develop all geoprocessing services from scratch. The GeoBrain project can not afford to develop a large number of services in this way. The strategy used by the project is to make existing geospatial processing package web-service enabled. The software package chosen by the project is an open source GIS package called GRASS [11]. Currently GeoBrain has implemented more than 200 Web geospatial processing services; most of them are converted from GRASS.

C. Geoprocessing Modeling and Knowledge Sharing

GeoBrain provides not only customized data to users but also an open, interoperable platform for users to construct complex Web-executable geoprocessing models, run the models on line, and share the captured knowledge with peers. All analysis functions in GeoBrain are implemented as chainable Web services, which can be used to construct complex geoprocessing models by chaining them together. GeoBrain addresses geospatial interoperability and sharing through all its capabilities, but especially through this geospatial modeling and knowledge sharing capability. Currently this capability in GeoBrain is still in prototype stage, only allowing users to construct geospatial processing models by chaining some specific analysis functions together and to execute them at the GeoBrain workflow engine called as BPELPower, and then, to send the results back to users.

III. GEOBRAIN ARCHITECTURE AND COMPONENTS

GeoBrain is built on a profound foundation of NASA EOS data and computational resources as well as information technologies. The three tiers GeoBrain architecture (Fig. 1) embodies an integrated infrastructure to provide the above discussed GeoBrain functionalities and technologies. The following will give a brief explanation for each tier.

A. Interoperable Data Server Tier

This bottom tier consists of all kinds of data servers providing data to the middle tier through a common data environment. The common data environment is a set of standard interfaces, including OGC WMS, WCS, CSW and Web Feature Service (WFS), for finding and access data in diverse data archives seamlessly in a distributed environment. GeoBrain has diverse data sources, ranging from small data providers to multiple-petabyte NASA EOSDIS (EOS Data Information System) data archives.

B. Middleware Service Tier

This middle tier is the geospatial service and knowledge management tier, consisting multiple components that perform geospatial data processing, information extraction, and knowledge management. The important components include Geospatial Service Module Warehouse, Geospatial Model/Workflow Warehouse, Virtual Product/Workflow manager, Model/Workflow Execution Manager, Interactive Model/Workflow Editor Server, Service Module Development Environment, Peer-review and Collaborative Development Server, Product and Service Publishing Interface.

C. Client Tier

GeoBrain provides a multi-protocol geo-information client (MPGC) to users for free. MPGC is an integrated client, providing not only accesses to all virtual and real data/information provided by GeoBrain and all other OGC-compliant providers but also the geospatial modeling/ workflow interfaces, peer-review interfaces, and the collaborative development interfaces [12].

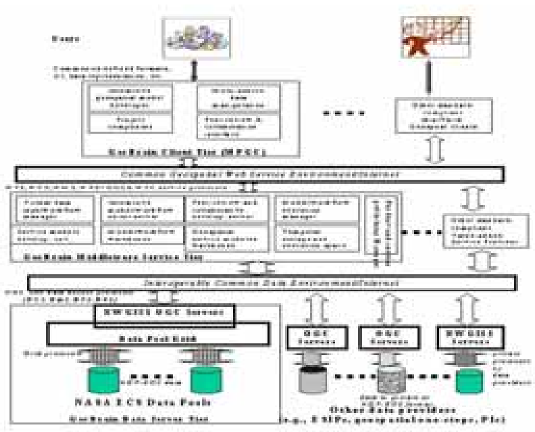

Figure 1. GeoBrain Architecture

IV. USING GEOBRAIN

GeoBrain is being developed to provide a data-enhanced online learning and research environment for remote sensing and Earth science disciplines. The latest geospatial Web service technologies implemented in GeoBrain enables the IPODAS, online data analysis, geoprocessing modeling, and knowledge sharing capabilities. Such capabilities can benefit educators, students and researchers a lot. In order for readers to better understand GeoBrain functionalities and how to utilize GeoBrain in their education and research activities, the followings will illustrate the uses of GeoBrain through two major perspectives.

A. Using GeoBrain in Research

A typical data-intensive remote sensing or Earth science research involves the following eight steps:

1) Find a real-world problem to solve
2) Develop/Modify a hypothesis/model
3) Implement the model/develop analysis procedure at computer systems and determine the data requirements
4) Search, find, and order the data from data providers
5) Preprocess the data into the ready-to-analysis form (e.g. reprojection, reformatting, subsetting, subsampling, geometric/radiometric correction)
6) Execute the model/analysis procedure to obtain the results
7) Analyze and validate the results
8) Repeat steps 2-7 until the problem is solved

Without using GeoBrain, a researcher may need to spend huge amount of time and computing resources for steps 2-6. Therefore, many projects requiring real or near-real time data can not be conducted. With GeoBrain, steps 3-6 can be fully automated, saving significant amount of time and computing resources for users. In addition, the geoprocessing modeling and knowledge sharing capability of GeoBrain can provide useful helps to users at step 2.

B. Using GeoBrain in Classroom Teaching

GeoBrain is configured for open access through Web. With the functionality and capacity of the GeoBrain system, the requirements at the user's side become very light. An Internet – connected PC capable of running a Java client is the only necessity for users. Fast Internet connection is not necessary at the user site, because GeoBrain does the data reduction and analysis at server side and users need only to retrieve the results rather than all the raw data, even though GeoBrain can provide fast access to raw data too. This brings significant advantage to classroom teaching in those universities who don't have enough software systems and resources for students to dynamically analyze EOS data due to the huge data volume.

Currently very few universities have the hardware and software resources available for each student to handle multi-terabytes of EOS and other geospatial data in simulation and modeling for solving global-scale problems. GeoBrain provides a solution to this problem by serving higher-education users as 1) an unlimited global geo-data source, 2) an on-line data analysis system, 3) an on-line platform for geoprocessing modeling, 4) a platform for geospatial knowledge sharing. The system gives students and faculty a data-rich geospatial learning and research environment that was never available to them before. As a result, students can be exposed to richness of EOS data and learn how to use this vast amount of data in the real-world applications through GeoBrain. The challenging task to prepare them as global-view workforce becomes easier and more practical.

V. DEMONSTRATION

The GeoBrain project is a 5-year project starting from February 2004. The data access and analysis services have been operational since April 2005. The capabilities of geospatial modeling and knowledge sharing are still in prototype stage. Simple demonstrations of both operational and prototype capabilities are shown in the followings.

A. Operational Capabilities

We use GeoBrain data download web site and the MPGC client to show how GeoBrain provides better and easier access and use of vast NASA EOS data.

MPGC provides a single point of entry for accessing to OGC-compliant data and services available around the world and for requesting any subsets of multi-dimensional and multi-temporal geospatial data in a user-specified geographic region. MPGC also can access Web geospatial processing services to generate value-added data products on demand. Moreover, at the local machine where MPGC is running it also can 1) reformat the retrieved dataset into a data format specified by the user; 2) provide robust visualization and analysis tools for multi-source geospatial data; and 3) support multiple coverage, feature and map formats used by different servers. Those formats include HDF, GeoTiff, GML, JPG, PNG, and GIF. The website for download MPGC is http://geobrain.laits.gmu.edu/mpgc. Fig. 2 is a snapshot of MPGC screen display.

Some users may prefer to access data and services provided by GeoBrain through a web browser instead of standalone clients which require users to install the software at their desktop first. In order to better serve the user community, a GeoBrain data download website (http://geobrain.laits.gmu.edu:8099/cswquery-csf/) is developed for users to directly obtain the data they want through any web browser. The web site provides data discovery, subsetting, resampling, reformatting, and reprojection services. A screenshot of accessing this web site is shown in Fig. 3.

B. *Prototype of Geospatial Modeling*

Geospatial knowledge can be represented in an abstract geospatial processing model and the virtual product generated by constructing the model. Fig. 4 shows the construction of an abstract geospatial processing model of landslide susceptibility using GeoBrain Abstract Model Designer. After the model is constructed, a virtual product called Landslide Susceptibility immediately becomes available to users. When a user request the product for a specific time and geographic area, the GeoBrain system will generate the requested product on-line and deliver the on-demand product to users. Fig. 5 shows an example of such a product for the Alameda County, California.

Figure 2. A snapshot of using MPGC

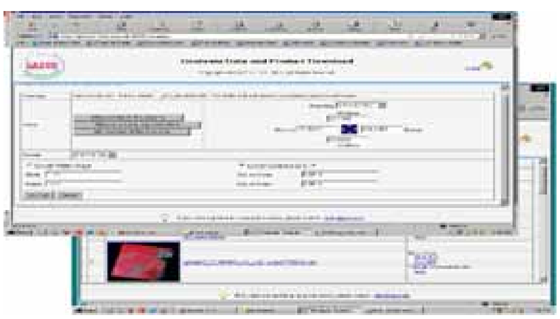
Figure 3. Direct GeoBrain data download

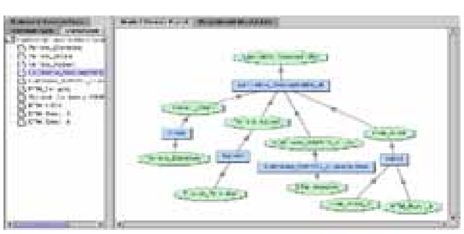
Figure 4. An abstract geospatial processing model

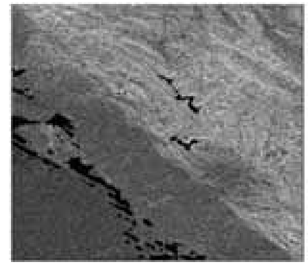
Figure 5. A landslide susceptibility product generated

ACKNOWLEDGMENT

This research is funded by a grant from NASA Earth Science Research, Education, and Applications Solution Network (REASoN) program (NNG04GE61A, PI: Dr. Liping DI).

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