

INTEGRATING VIRTUAL GLOBES AND WEB SERVICE TECHNOLOGIES FOR HIGHER-EDUCATION TEACHING AND RESEARCH

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ABSTRACT:

The emergence of Virtual Globe software systems offer tremendous opportunities, such as providing a new generation of learning tools to help students digest large-scale geospatial information about the world, and supporting domain expert analyses in an interactive three-dimensional virtual environment. In the meantime, Web Service technologies, especially those standards-based interoperable geospatial services, make a large amount of geo-processing functionalities easily accessible to educational users and researchers like their local resources. This paper presents a recent effort funded by an ISPRS Scientific Initiative project to integrate Virtual Globes and Web Service technologies for higher-education teaching and research. The integration combines the visualization and communication power of Virtual Globes with the powerful analysis functionalities of geospatial Web Services to help students and researchers investigate various scientific problems in an environment with natural and intuitive user experiences. This integration will provide analysis-enhanced Virtual Globes for in-classroom teaching and scientific research. Reports on recent progresses are provided.

1. INTRODUCTION

Virtual Globes are being used frequently to bring the globe-scale geospatial information to our fingertips. It is capable of letting users freely fly anywhere on a virtual Earth, with different views of Earth such as satellite imagery, geographical features, terrain, 3D buildings, and advanced stars, atmosphere or sunlight effects. More specifically, it allows users to add annotations, fuse heterogeneous geospatial data from multiple sources, conduct network-based local-to-global multi-resolution visualization, and share data with others. The emergence of Virtual Globe software systems such as Google Earth, Microsoft Virtual Earth, NASA World Wind revolutionizes the traditional way of using geospatial information, making geospatial information easily accessible and usable by general public users instead of only domain experts. The wide popularity of these Virtual Globe software systems in the geospatial and general communities inspires more ways of exploring and using Virtual Globes. One potential is to teach spatial concepts and analysis in classrooms, since Virtual Globes can provide a better understanding of traditional topics of geography such as showing geo-referenced globe and maps and displaying geospatial analysis results.

The growth of the Web has resulted in the Web-based sharing of large volumes of distributed geospatial data and computational resources. Processing heterogeneous and distributed data into information requires interoperability among diverse data. This necessity led to the development of a set of standard interfaces for geospatial Web Services, and a number of interoperable services have been available in the geospatial community. Most of these services are compliant with the Open Geospatial Consortium (OGC) standards such as Web Feature Service (WFS), Web Map Service (WMS), Web Coverage Service (WCS), Web Processing Service (WPS), and Catalogue Service for Web (CSW). These Web Service technologies, especially those standards-based interoperable

geospatial services, make a large amount of geo-processing functionalities easily accessible to educational users and researchers like their local resources.

The integration of Virtual Globes and interoperable geospatial Web Services will extend the current capabilities of Virtual Globes by focusing primarily on enabling higher-education teaching and scientific research, with its heavy analysis demands, as opposed to focusing initially on visualization and annotation. This integration will provide analysis-enhanced Virtual Globes for in-classroom teaching and scientific research. Therefore, it will enhance the common good of all geospatial users in that they will have a platform that are easily accessible and help themselves perceive and explore world space and geo-scientific processes. The results will be tested through GeoGlobe system. This paper describes the design and recent progresses of this work funded by an ISPRS Scientific Initiative project. The remainder of this paper is organized as follows: Section 2 introduces the literature in this field; Section 3 presents the approaches adopted and Section 4 describes the system implementation details and progresses; Conclusions and pointers to future work are given in Section 5.

2. RELATED WORK

Geographical Information System (GIS) tools have been recognized as an important way to advance geo-related education and research (NSF, 1994). Ever since the emergence of Google Earth in 2005, the easy access to the geospatial data through Virtual Globes has attracted many educational and scientific users. The Google Corporation has launched Google's Geo Education site, where both general users and researchers can learn and use Google's geo-related products including Google Earth and Maps. This suite of products has proved to be powerful enough to help students conceptualize, visualize, share, and communicate information about the world around them.

There is also some ongoing effort to use Web Service technologies to allow students and researchers from locations all around the world to access and analyze online Earth science data. The National Aeronautics and Space Administration (NASA) Earth Science Research, Education, and Applications Solution Network (REASoN) program funded a 5-year project named NASA EOS Higher Education Alliance: Mobilization of NASA EOS Data and Information through Web Services and Knowledge Management Technologies for Higher Education Teaching and Research, shortly known as NEHEA GeoBrain, in 2004 (Di, 2004). This online environment based on GeoBrain enables easy, open, seamless, and on demand discovery, access, retrieval, visualization and analysis of distributed geospatial data, information, services, and models from any computer connected to the Internet, thus it is able to serve the different needs of global Earth sciences research and higher education communities, bridge gaps between data user needs and provider capabilities, and greatly enhance use of geospatial data (Deng and Di, 2009).

The work in this paper goes further to take the best of both by integrating Virtual Globes and Web Service technologies, thus providing a powerful tool for users to conduct educational and research activities in a more natural way.

3. APPROACHES

The main work of this ISPRS-funded project is to integrate Virtual Globes and geospatial Web Service technologies. Based on our preliminary analysis of the two technologies, we propose the integration takes place at two points. The first one is to make geospatial Web Service accessible through clients of Virtual Globes. The second one is to integrate geospatial Web Service servers and front-end of Virtual Globes servers, making data managed by Virtual Globes accessible through geospatial Web services.

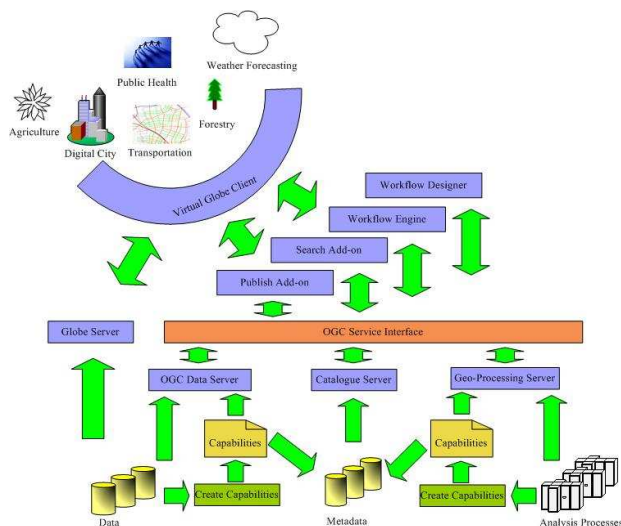


Figure 1. The integration architecture of analysis-enhanced Virtual Globes

The integration will take place in three phases. Figure 1 shows the proposed architecture of the integrated system. The *first* phase is the testbed and initial integration, which include the setup of the development environment, preliminary design of the integration, and implementation of OGC data service protocol access to Virtual Globe-managed data. OGC Web data

service protocols such as WFS, WMS and WCS allow geospatial services and value-added applications to access diverse data provided by different providers in a standard way without worrying about their internal handling of data.

The *second* phase is the implementation of access from Virtual Globe clients to geospatial Web services and services integration. The approach to services integration is to follow the “publish-find-bind” paradigm in the Service-Oriented Architecture (SOA). OGC has developed a series of interface specifications following this paradigm. In addition to OGC Web data service protocols, OGC WPS can provide conventional GIS analysis functionalities over the Web. The registry service, i.e. OGC CSW, provides the discovery not only on the services, but also on the geospatial data. Virtual Globes, therefore, should be able to discover, bind and invoke these standards-based interoperable services. Service composition introduces a new operation into SOA, chaining, which combines services into a dependent series to accomplish a larger task. Workflow designers and engines will be plug into clients of Virtual Globes as add-ons to construct and execute service chains.

The *third* phase is the user forum development and operational support. We will set up a user forum Web site to encourage teachers and researchers to share their experiences, incorporate the new Virtual Globes into existing courses and research activities, and cooperatively develop new courses. With the requirements and experiences from end-user community, we will identify priorities of services for those new courses and provide support correspondingly.

4. IMPLEMENTATION

4.1 Development of geoprocessing Web services

To support geoprocessing over the Web, a Web service toolkit, named GeoPW (<http://geopw.whu.edu.cn/geopw.html>), has been implemented (Yue et al., 2009). It leverages Web Services, legacy GIS software, and OGC specifications to make traditional desktop analysis functions configurable, accessible, and interoperable over the Web. Geoprocessing services are provided by middleware wrapping legacy GIS analysis components to provide OGC WPS interfaces. These legacy components include analysis utilities of GIS software systems GRASS and GeoStar. Geographic Resources Analysis Support System, commonly referred to as GRASS GIS, is one of the most widely used open source GIS software system. GeoStar is a leading enterprise GIS software system in China. It has been developed by the State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing (LIESMARS), Wuhan University (formerly Wuhan Technical University of Surveying and Mapping) since 1992 (Li et al., 1999). Based on the geoprocessing functions provided by GRASS and GeoStar, GeoPW has already developed over one hundred geoprocessing services. These services provides geoprocessing functions including GIS vector and raster analysis, network analysis, data processing, geostatistical analysis, and hydrological analysis. We group them into ten categories: Vector Spatial Analysis, Vector Geometry Operation, Vector Network Analysis, Vector Data Processing, Raster Spatial Analysis, Raster Data Processing, Raster Aggregation, Hydrologic Analysis, Geostatistics, and Others (Figure 2).



Figure 2. Web access entry of GeoPW

All these services are deployed on the Hewlett-Packard (HP) blade servers (Intel® Xeon® 5110 1.6GHz, 4GB RAM) located at LIESMARS. GRASS software is installed in a server blade with the UNIX operation system, and GeoStar is located in another server blade with Microsoft Windows operation system. All services are provided to the public through a single Web access point on one server blade that is public accessible. This Web entry point is implemented using JAVA servlets to redirect the request to WPS processes deployed in internal server blades. Currently, services in GeoPW has wrapped most vector and raster analysis functions of GRASS, and demonstrated the wrapper for GeoStar by exposing its spatial buffer and overlay analysis functions. More processes are being developed, and after passing tests, will be deployed into distributed internal server blades and available for public users.

4.2 Implementation of OGC data service protocol access to Virtual Globe-managed data

The data managed by Virtual Globes can be either accessed directly through the front-end of Virtual Globe servers, or they can be augmented with capabilities document and published through OGC standards-compliant data servers. Similar to other popular Virtual Globe software, GeoGlobe uses a hierarchical tiling technique (or named pyramid structure). For any given area, regional low-resolution tiles are first downloaded, followed by medium-resolution tiles and finally local high-resolution tiles. Data tiles following a pyramid structure are pre-built and provided through GeoGlobe servers. Such pyramid structure allows the visualisation of multi-terabyte datasets. Implementation of OGC data service protocol access such as WCS to Virtual Globe-managed data allows geospatial services and value-added applications to access data in an interoperable way.

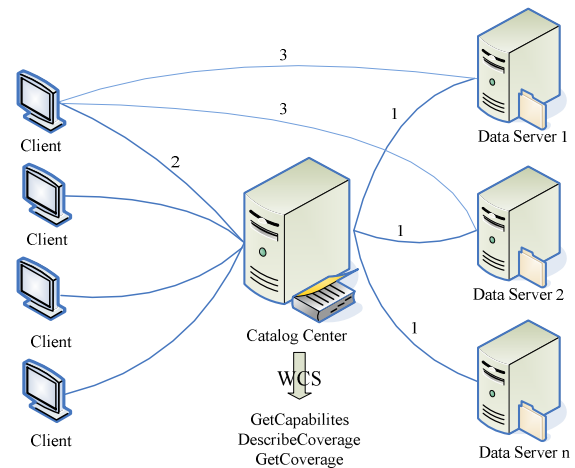


Figure 3. The Architecture of the GeoGlobe WCS

The internal management of the GeoGlobe server is based on a multi-server technology. Multiple data servers are deployed in a wide area network (WAN), registered into a catalogue center to support a publish-find-bind paradigm (Figure 3):

- 1) Publish: Data server nodes are registered into the Catalog Center. The meta-information of pyramid, such as pyramid identification, lever number, pixel resolution and geospatial bounding box, are registered;
- 2) Find: Client nodes login into the Catalog Center and discover the pyramids published in the WAN;
- 3) Bind: Client nodes bind the discovered data node and download pyramid tiles.

The deployment of this multi-server technology brings the following advantages:

- 1) Data server nodes can be distributed into WAN instead of the same local area network (LAN);
- 2) Client nodes can download data tiles from data server nodes directly without passing through the Catalog Center, thus saving the cost of network transmission.
- 3) A wide range of load-balancing strategies, such as random selection and polling, can be integrated when choosing one among those data servers that can provide the same pyramid tiles.;
- 4) Data server nodes and the Catalog Center are loosely coupled. Thus more data server nodes can be incorporated easily into the GeoGlobe server.

The WCS interface and protocol for GeoGlobe server is implemented at the Catalogue Center (Figure 3). It can not only provides all meta-information for pyramid tiles registered in the Catalogue Center, but also support the load-balancing among multiple data server nodes providing the same pyramid tiles. The GetCapabilities and DescribeCoverage operations in the WCS interface are implemented based on the registered meta-information stored locally at the Catalogue Center. The implementation of the GetCoverage operation includes the following steps: First, the service selects the data server node with a lower load; and then it downloads the tiles covered by the requested bounding box from the data node; finally, it outputs the coverage data through image data processing functions based on these data tiles.

4.3 Preliminary implementation of access from Virtual Globe clients to geospatial Web services and services integration

SOA provides a basis for construction of a distributed, dynamic, flexible, and re-configurable service system over Internet that can meet many different users' information requirements. Following the publish-find-bind paradigm in SOA, Virtual Globes, therefore, should be able to discover, bind and invoke these standards-based interoperable services.

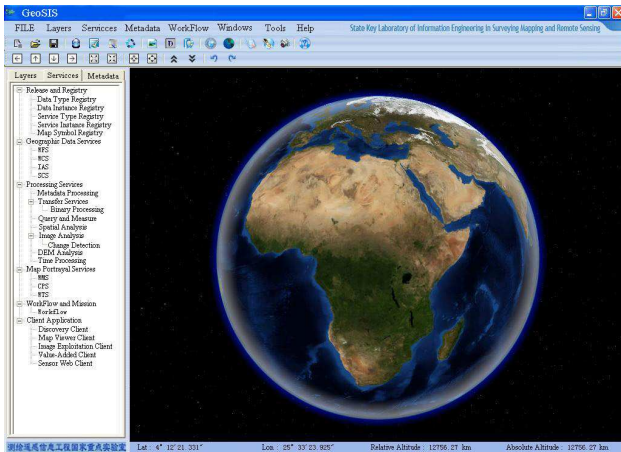


Figure 4. The user interface of the GeoGlobe Client

Figure 4 shows the user interface of the GeoGlobe client. The tree on the left panel lists the available services registered in the registration center, e.g. geospatial data services, processing services, and map portrayal services. The registration center is a Web-based registry service following the OGC CSW specification. Currently, there are two prominent general information models for registry services: the ebXML Registry Information Model (eBIM) and the Universal Discovery Description and Integration (UDDI) model. For the geospatial community, eBIM is more general and extensible because it provides comprehensive facilities, based on the ISO 11179 set of standards, to manage metadata. OGC has developed and recommended an eBIM profile for CSW. This profile introduces an eBIM-based catalogue information model for publication and discovery of geospatial information. The metadata for both geospatial Web services and geospatial data are registered in a CSW-eBIM server. Users can view the information of a service by clicking it on the tree in the Figure 4.

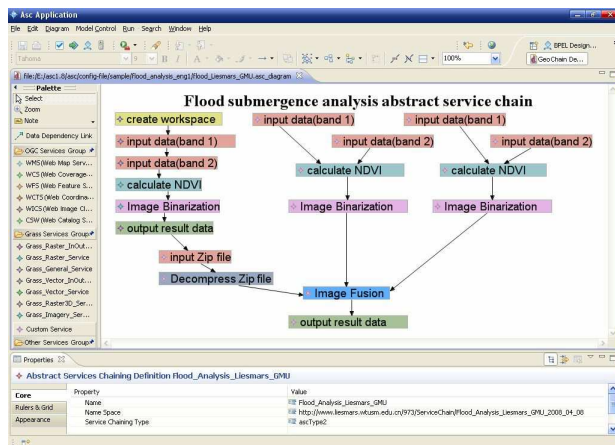


Figure 5. A service chain for flood submergence analysis

In a service-oriented environment, where large volumes of geospatial data and diverse geo-processing functions are accessible as services, it is necessary to create service chains as geo-processing workflows to solve complex geospatial problems. A geospatial services chaining tool is developed based on Eclipse Rich Client Platform (RCP). It is able to create geoprocessing models by dragging and dropping atomic geoprocessing process, and transform the geoprocessing model into an executable service chain represented using a service composition language, i.e. Web Services Business Process Execution Language (WSBPEL), shortly known as BPEL. Figure 5 illustrates an example of a geoprocessing model for a flood submergence analysis. The atomic process models on the left column of the palette are chosen and dragged to the right area in the right panel, and then composed together through data flow and control flow links to generate a logical workflow that meet specific requirements of the flood submergence analysis. This logical workflow is stored as a process model contributed by experts. It can be transformed into a BPEL service chain and executed by the BPEL workflow engine. The model itself is reusable and evolvable.

5. CONCLUSTIONS AND FUTURE WORK

This paper presents current progresses towards the integration of Virtual Globes and standards-compliant geospatial Web Services to provide an analysis-enhanced Virtual Globe for globe geospatial information sharing, visualization, and analysis. The system shows how multi-source and multi-scale data can be easily accessible and processable through Virtual Globes and geospatial Web Services. Standards-compliant Interoperable data service and geoprocessing services can be easily chained together for complex geospatial data analysis and Earth science modelling.

The system will make it much easier and faster for students to learn and perceive geospatial world, concepts and processes. The researchers can investigate a wide range of geospatial problems through the large-scale geospatial data and analysis functions provided by either Virtual Globe servers or geospatial Web services distributed at worldwide locations. The analysis processes, archived as service chains in catalogue services, can be shared and discovered.

The next step of this work is to exercise the results of this work in existing courses as an experiment in the validity and potential of in-classroom use. This can help to evaluate how wide a range of educational goals a Virtual globe can achieve, what scope of geospatial data and functions is practical to be used, and what the difficulty is when considering a Virtual Globe for classroom use. More geoprocessing services and models, contributed by globally distributed organizations, can be registered into our system after going through tests and peer-reviewed processes.

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