

Final Report

2009 ISPRS SCIENCE INITIATIVE

Title:

**Integrating Virtual Globe and Web Service Technologies for ISPRS
Higher-Education Teaching and Research**

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1. Project objectives

The objective of this proposed research is to integrate Virtual Globes and geospatial Web Services. 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 provides analysis-enhanced Virtual Globes for in-classroom teaching and scientific research.

2. Background and research

Virtual Globe software such as Google Earth, Microsoft Virtual Earth, NASA World Wind, and EarthBrowser 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 geoprocessing functionalities easily accessible to educational users and researchers like their local resources. The integration of Virtual Globes and interoperable geospatial Web Services extends 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.

The main work of this ISPRS-funded project is to integrate Virtual Globes and geospatial Web Service technologies. 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. The research is directed to bring a virtual learning and research environment to the desktops of students and professors in that they can have a platform that are easily accessible and help themselves perceive and explore world space and geoscientific processes.

3. Accomplishments

3.1. Development of key technologies

3.1.1. 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. 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 Open Geospatial Consortium (OGC) Web Processing Service (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. Based on the functions provided by GRASS and GeoStar, GeoPW has already developed many 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 1 shows the number of services in different categories.

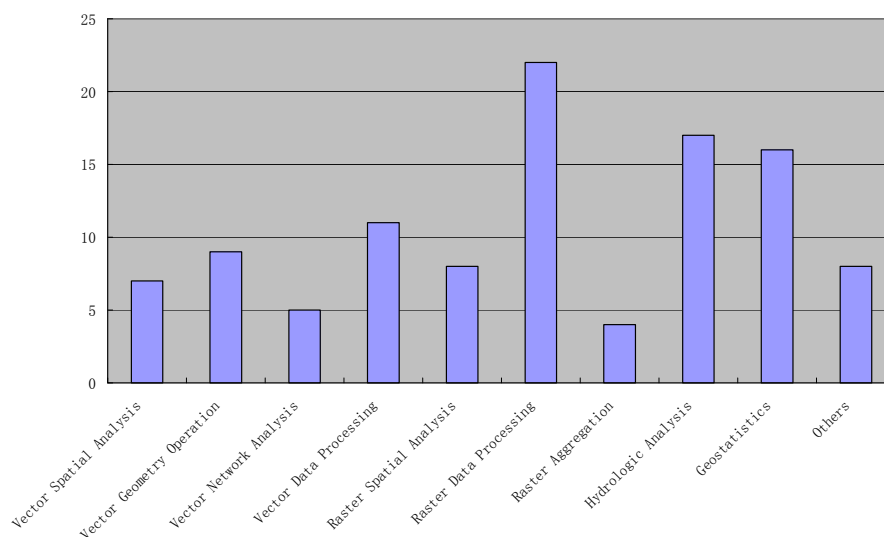


Figure 1. Services distribution in different categories of geoprocessing functions

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 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 servlets to redirect the

request to 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 through 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.



Figure 2. Web access entry of GeoPW

The latest news about GeoPW and all developed geoprocessing services are available at <http://geopw.whu.edu.cn/geopw.html> (Figure 2). The process description and one testing example for each process are provided through Web page links. There is a link on the home page that provides a guide for GeoPW. The guide provides Web addresses for geoprocessing services and process descriptions and testing examples for analysis functions provides by both GeoStar and GRASS.

3.1.2. 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. The implementation is tested through GeoGlobe system. GeoGlobe is Virtual Globe software, which has been selected as the primary geospatial solution for serving

national and regional fundamental geospatial information over the Web in state geoinformatic centers of China. 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 visualization 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.

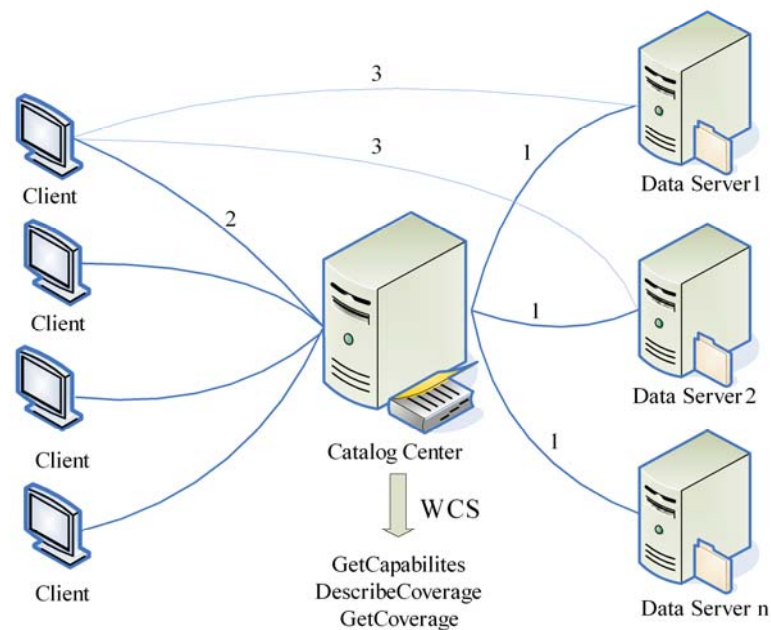


Figure 3. The Architecture of the GeoGlobe WCS

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.

3.1.3. Implementation of access from Virtual Globe clients to geospatial Web services and services integration

The service-oriented architecture (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.

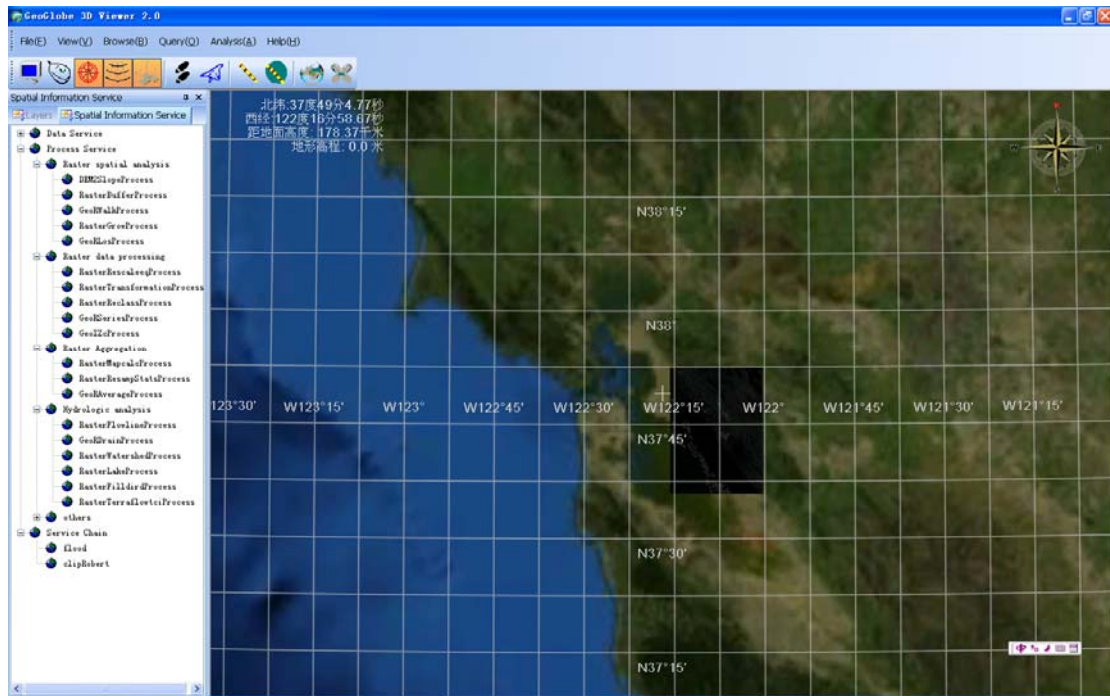


Figure 4. The user interface of the GeoGlobe Client

Figure 4 shows the user interface of the GeoGlobe client. The left tree 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 Catalogue Service for Web (CSW) specification. Currently, there are two prominent general information models for registry services: the ebXML Registry Information Model (ebRIM) and the Universal Discovery Description and Integration (UDDI) model. For the geospatial community, ebRIM 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 ebRIM profile for CSW. This profile introduces an ebRIM-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-ebRIM server. Users can view the information of a service by clicking it on the tree in the Figure 4.

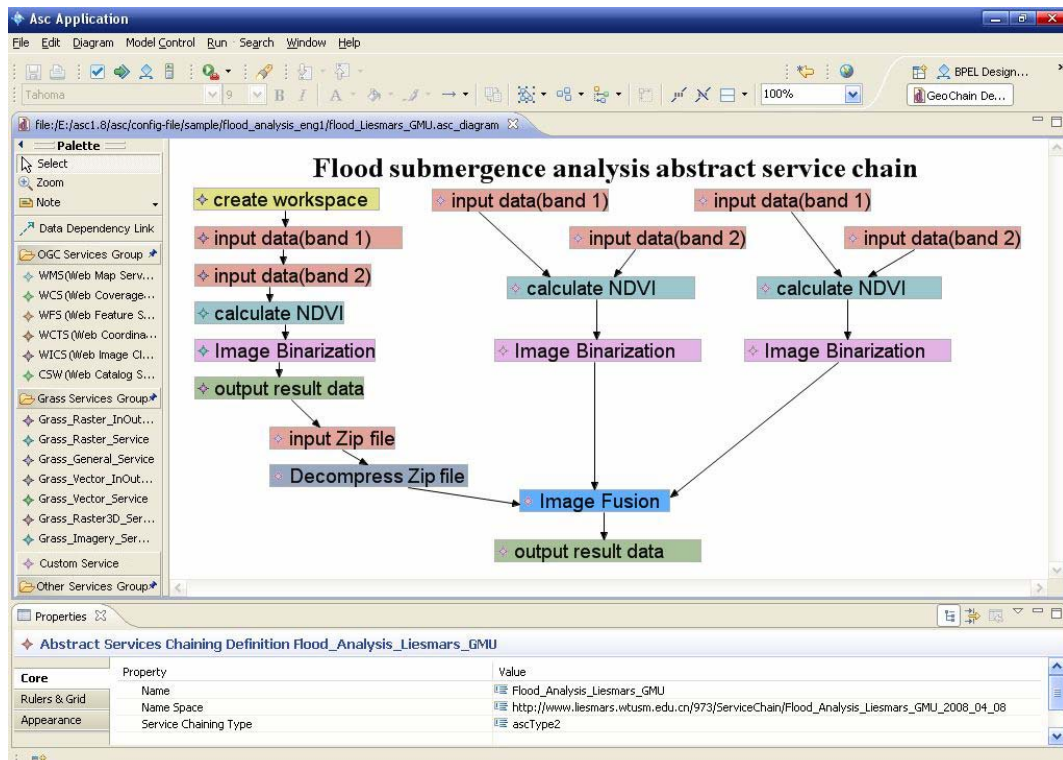


Figure 5. A service chain for flood submergence analysis

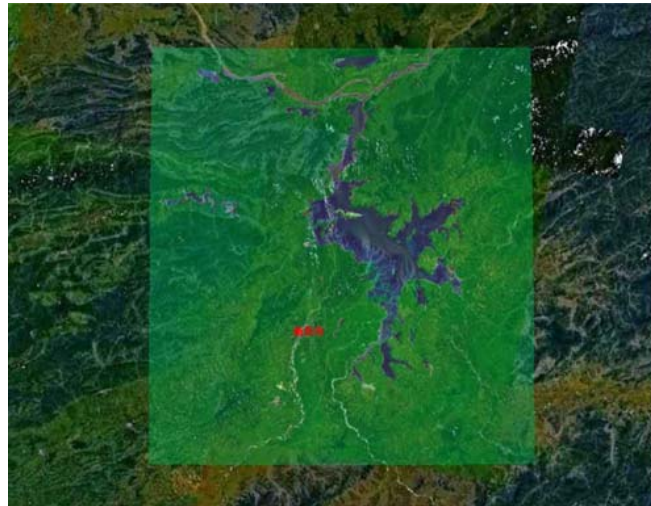


Figure 6. The result of the service chain for flood submergence analysis

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 service chain composed for flood submergence analysis. The useful services from the palette on the left column are chosen and dragged to the right area in the right panel, and then these services are chained in a logical workflow according to the specific requirements of flood submergence analysis. Finally, an abstract chain will be built and stored as an expert process model. The abstract chain will be transformed into a BPEL service chain and executed by the workflow engine. This kind of abstract chains can be reused and adjusted for different applications. Figure 6 presents the result of the service chain for flood submergence analysis. The dark part in the center of the map is the area submerged by flood.

Some tools are available to the public at <http://www.iccgs.whu.edu.cn/english/tools/index.html>.

3.2. Educational and academic exchanges

3.2.1. National University Advanced Seminar on Web-based multi-source geospatial information sharing and service

The National University Advanced Seminar on “Web-based multi-source geospatial information sharing and service” was hosted by the State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing (LIESMARS), Wuhan University, from 19th to 24th July 2009. The seminar was co-organized by the LIESMARS and Wuda Geo informatics Co., Ltd. Educators and researchers from fourteen universities in China including Peking University, Zhejiang University, and Nanjing University joined the meeting and discussed the latest theories, methods, technologies, and products on geospatial services and virtual globes.



Figure 7. Snapshot of Seminar

Another goal of this seminar is to use the joint power of universities and institutes to extend the scope of usage of Virtual Globe systems and geospatial web services, and provide an open service platform for national wide geoinformation-related researches, experiments, and applications. In particular, a tutorial session is held to introduce the usage of GeoGlobe.



Figure 8. GeoGlobe training in the computer lab

3.2.2. Organization of the ISPRS workshop for educational and research users

The ISPRS Wuhan Workshop 2009 "Virtual Changing Globe for Visualisation and Analysis" was hosted by the State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing (LIESMARS), Wuhan University, from 27th to 28th October 2009. The website is <http://www.lmars.whu.edu.cn/vcgva2009/index.html>. The workshop was co-organized by the ISPRS working groups WG IV/4 (Virtual Globes and Context-Aware Visualisation/Analysis) and WG VII/5 (Methods for Change Detection and Process Modelling). Representatives in universities, research institutions, and private industry attended the workshop. Experts and scholars from China, USA, UK and other countries have delivered 4 keynotes, 18 oral presentations and related demonstrations.

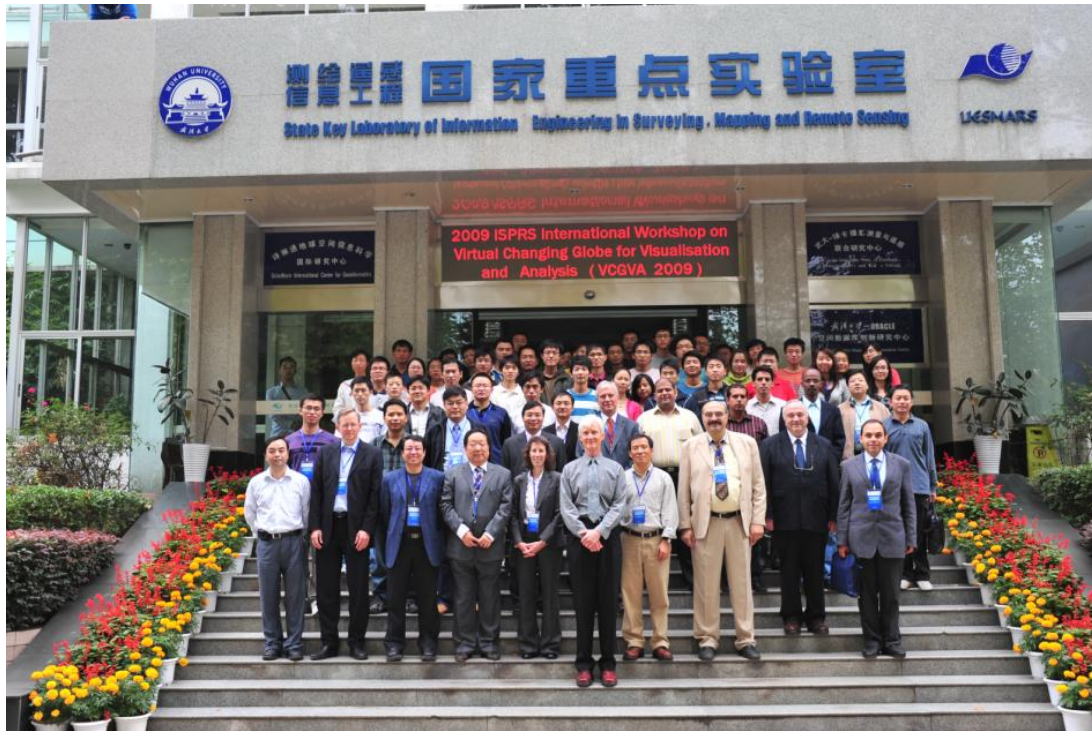


Figure 9. Group Photo for Participants

In the opening ceremony of the workshop on 27 October, Prof. Chuangbing Zhou, the vice president of Wuhan University, Prof. Deren Li, the Chairman of the Academic Committee of LIESMARS, Prof. Ammatzia Peled, the Second Vice President of ISPRS, and Prof. Marguerite Madden, the president of ISPRS TC IV, delivered welcome addresses.



Figure 10. The opening ceremony of the workshop

The keynotes are provided respectively by Professor Deren Li from LIESMARS of Wuhan University, Professor John Townshend from University of Maryland at College Park, USA, Dr. Vincent Tao from Microsoft Virtual Earth, and Mr. Patrick Hogan from NASA World Wind. The main workshop consisted of a technical program of four oral sessions, focusing on Virtual Globe, Visualization and Analysis, Virtual Globe Case Studies, Spatio-Temporal Process Modeling and Methods of Change Detection. At the end of the workshop, demonstrations are provided, including multi-source spatial information sharing and service software platform – GeoGlobe, and integration of Geospatial Web Service and Virtual Globe.

Conference proceedings are available through the ISPRS Archives: ISPRS Wuhan 2009 Workshop Virtual Changing Globe for Visualisation and Analysis, Wuhan, China 27 – 28 October 2009, ISPRS Volume No. XXXVIII- 4/W10. Archives ISSN No.:1682-1777. 116p.

3.2.3. Conferences attended / Lectures delivered

(1) Professor Jianya Gong, the chair of ISPRS Working Group IV/4 - "Virtual Globes and Context-Aware Visualisation/Analysis", gave an invited talk, entitled "Multi-Sources Geospatial Information Integration and Service through Virtual Globe", at the *Chinese National Geographic Information Industry Summit conference*, 1-2 July, 2009, Beijing, China.

(2) Dr. Maged N. Kamel Boulos, the co-chair of ISPRS Working Group IV/4 - "Virtual Globes and Context-Aware Visualisation/Analysis", presented a new vision of emergency and public health situation rooms that leverage and harness the powers of the social Web ("Web 2.0"), the 3-D Web, and Internet GIS, at the *2009 International Workshop on Virtual Changing Globe for Visualisation and Analysis (VCGVA 2009)*, Wuhan, China, October 27-28, 2009.

(3) Dr. Peng Yue, the secretary of ISPRS Working Group IV/4 - "Virtual Globes and Context-Aware Visualisation/Analysis", presents the technical effort of this project at the *2009 International Workshop on Virtual Changing Globe for Visualisation and Analysis (VCGVA 2009)*, Wuhan, China, October 27-28, 2009.

(4) Dr. Peng Yue, the secretary of ISPRS Working Group IV/4 - "Virtual Globes and Context-Aware Visualisation/Analysis", presents the development of geoprocessing Web services at the *9th International Symposium on Web and Wireless Geographical Information Systems (W2GIS 2009)*, 7 & 8 December 2009, Maynooth, Ireland.

We also plan to attend the ISPRS Technical Commission (TC) IV Mid-Congress Symposium, 15-19 November 2010 in Orlando, Florida, USA, and present the platform to the wider public.

3.3. In-classroom teaching and research

The GIS graduate program in LIESMARS of Wuhan University offers two courses: Principle and technology of Web GIS and Geospatial Information Service. The previous one is designed to introduce students to concepts, methods, technologies utilized in the field of Web-based Geographic Information Systems (GIS). Educators therefore use GeoGlobe software to create visualizations of geospatial data that can be used for education and research. The latter course focuses on introducing the latest development of service computing technologies and its applications in geospatial domain. GeoPW therefore offers service-oriented powerful analysis utilities, which can be used for technological understanding and online spatial analysis.

The educational and research experiments in existing courses shows that virtual globes can help students and researchers perceive and explore world space in a natural and intuitive way. The Web-based local-to-global multi-resolution visualization of diverse data, including satellite imagery, geographical features, terrain, 3D buildings, and advanced stars or atmosphere, can help students specialized in GIS understand the organization, transmission, and visualization mechanism of geospatial information in the Web-based environment. The creation, execution and its result visualization of geospatial services such as WCS provided by GeoGlobe demonstrate the practice on geospatial information sharing and services, and illustrate characteristics and applications of geospatial information services in the Web-based environment. Integration of GeoGlobe and GeoPW shows that functions in Virtual Globes can be enriched with more analysis functions. Such analysis-enhanced Virtual Globes can increase the understanding of the role of Virtual Globes to support both applications in the general public and domain areas.

3.4. Publications

(1) Gong, J., Xiang, L., Chen, J., and Yue, P., 2009. Multi-Sources Geospatial Information Integration and Service through Virtual Globe. In: *Proceedings of the Chinese National Geographic Information Industry Summit conference*, 1-2 July, 2009, Beijing, China (in Chinese).

(2) Gong, J., Yue, P., Xiang, L. and Chen, J., 2009. Integrating Virtual Globes and Web Service Technologies for Higher-Education Teaching and Research. In: *Proceedings of the 2009 ISPRS International Workshop on Virtual Changing Globe for Visualisation and Analysis (VCGVA 2009)*, October 27-28, 2009, Wuhan, China. ISPRS Volume No. XXXVIII- 4/W10. Archives ISSN No.:1682-1777.

(3) Boulos, M.N.K., 2009. Novel Emergency/Public Health Situation Rooms and More Using 4-D GIS. In: *Proceedings of the 2009 ISPRS International Workshop on Virtual Changing Globe for Visualisation and Analysis (VCGVA 2009)*, October 27-28, 2009, Wuhan, China. ISPRS Volume No. XXXVIII- 4/W10. Archives ISSN No.:1682-1777.

(4) Boulos, M.N.K., Warren, J., Gong, J., and Yue, P., 2010. Web GIS in practice

VIII: HTML5 and the canvas element for interactive online mapping. *International Journal of Health Geographics*. 2010, 9:14. DOI: 10.1186/1476-072X-9-14.

(5) Yue, P., Gong, J., Di, L., Yuan J., Sun L., and Wang Q., 2009. GeoPW: Towards the Geospatial Processing Web. In: *Proceedings of the 9th International Symposium on Web and Wireless Geographical Information Systems (W2GIS 2009)*. 7 & 8 December 2009, Maynooth, Ireland. *Lecture Notes in Computer Science (LNCS)* 5886, Springer, Berlin, Germany, pp. 25-38.

4. Expenditure

Expenditure Summary

1. Direct Labor (salaries, wages, fringe benefits)	\$5,564
2. Total Direct Labor Hours	
Senior Staff	170
Student	500
3. Other Direct Costs	
a. Equipment	
b. Consultants	
c. Materials and Supplies	\$966.1
d. Publication Costs/ Documentation/ Dissemination	\$1,055.3
e. Travel (10%)	\$775.6
f. Other	
4. Indirect Costs (10%)	\$929
5. Other Applicable Costs	
6. Total Costs	\$9,290