

The Emerging Concepts and Applications of the Spatial Web Portal

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Abstract

Geospatial metadata, data, and services have been widely collected, developed and deployed in recent years. This flourishing of geospatial resources also added to the problem of geospatial heterogeneity. Interoperability research and implementation are needed for advancement in potential solutions to integrate and interoperate these widely dispersed geospatial resources. We propose the Spatial Web Portal architecture to integrate and interoperate geospatial resources. The architecture leverages web-based computing, spatial web services, and web fragments to integrate geospatial metadata, data, analysis, and presentation, through distributed portlets: (1) Spatial web services are adopted to interoperate geospatial components. (2) Web portals are adopted to integrate web pages from web fragments generated by portlets. (3) W3C recommendations are adopted to provide access to remote portlets delegating geospatial components. (4) Java community specifications are adopted to facilitate the development and distribution of portlets. NASA's Earth Science Gateway (ESG) is designed and developed as an example to test the proposed architecture in sharing earth observations, simulations, and other geospatial resources. The proposed architecture and example system provide (a) a tested mechanism for interoperating geospatial resources at different levels, (b) an environment to test new interoperable concepts, and (c) a platform to support heterogeneous-geospatial-resource based applications of national and global significance, such as the Global Earth Observing System of Systems (GEOS) applications.

Introduction

Most geospatial resources today are separately collected, archived, managed, analyzed, and presented to suit different objectives at geographically dispersed locations and comput-

ers. Isolated, application-specific systems can impede the sharing of geospatial resources. One important approach to this problem is interoperability (Buehler and McKee, 1996).

Beginning in the early 1990s, the introduction of Web-based services into, and alongside, geospatial information systems (GIS), e.g., with the pioneering Xerox PARC Map Server (Plewe, 1997), sharpened the focus on geospatial interoperability. Around that time, the U.S. Federal Geographic Data Committee (FGDC) devised the National Spatial Data Infrastructure (NSDI; Clinton, 1994); the Open Geospatial Consortium (OGC) began to develop interface specifications for GIS services; the International Organization for Standardization (ISO) formed a Technical Committee to develop geospatial information standards (TC211 2006); and the U.S. National Science Foundation funded the Alexandria Digital Library project (Smith, 2006). A growing number of companies also developed and sold Web mapping products and services: examples include Mapquest, Inc. (Plewe, 1997), Autodesk™ MapGuide™, or ESRI ArcIMS® suite. Researchers and educators also made use of WEBGIS integration, resulting in WEBGIS courses (Foote *et al.*, 1997), books on Internet GIS (Peng and Tsou, 2003; Plewe, 1997), and research on web and wireless GIS (Huang *et al.*, 2001). At upper levels of government, U.S. Vice President Al Gore (1998) called for a "Digital Earth" to facilitate national and global geospatial information access and sharing.

The maturing World Wide Web has provided an increasingly useful basis for interoperability (Goodchild *et al.*, 2006). For example, the HyperText Transfer Protocol (HTTP; Fielding, 1999), the Extensible Markup Language (XML; W3C, 1996), and Web Services (W3C, 2002) have enabled such resources as the FGDC Geospatial Data Clearinghouse (FGDC, 1999), the USGS National Map (Groat, 2003), Google Earth (Butler, 2006), Microsoft® Virtual Earth (Microsoft, 2006), and the U.S. government Geospatial One-Stop portal.

Nonetheless, many operational challenges persist, including the integration and sharing of geospatial assets at different levels of abstraction and detail, or the aggregation of geospatial and other information assets to address domain-specific problems.

We propose the Spatial Web Portal (SWP) to address these challenges. SWP is based on portlet technologies (Hepper, 2006), Web Services for Remote Portlets (WSRP; Thompson, 2006), the Java Specification Request (JSR 168/268), and OGC Spatial Web Services. A Web portal integrates distributed contents onto a single web page: portlets are dynamic HTML fragments that draw their content from backend information services. We illustrate the general concept by means of the

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Earth Science Gateway (ESG; Evans and Bambacus, 2005), a portal providing access to NASA data, simulations, and research results to facilitate national (Birk, 2006) and global (GEO, 2005) applications.

The next section introduces a generic architecture for proposed SWP, and the design and implementation of the architecture using underpinning technologies followed by the introduction of ESG as an example of this architecture. The final section draws conclusions and discusses implications for interoperability.

Spatial Web Portal Architecture

The marriage between portals and geospatial interoperability was introduced in 2002 as an OGC (2002) Geospatial One Stop (GOS, 2007) portal initiative for interoperating geospatial services. Following the initiative, Rose (2004) worked on a geospatial portal architecture to leverage GIS components and OGC spatial web services including a set of clients, data services, catalog services, and portrayal services. At the same time, FGDC started the procurement of the GOS portal as a “one stop for federal, state, and local geographic data” (GOS, 2007). This focus of GOS on geographic information limits the functional developments and usage by communities other than geography.

To meet the challenges of interoperating widely geographically dispersed geospatial information and advance the interoperability practice, we propose the Spatial Web Portal architecture (Figure 1): (1) This architecture relies on *spatial web services wrapping legacy applications and services*. (2) Using these *spatial web services* and portlets, a *Spatial Web Portal* aggregates web pages (such as publish, search, view, metadata, and results views) to support different types of clients. (3) These pages in turn are integrated with other domain information to support *specific community*. (4) *Facilitating services* and *maintenance services* provides system

support to the operation of SWP. The design and implementation of the architecture is described in the following subsections. This architecture enables reuse and sharing of legacy components, reuse of portlets to wrap the legacy components through spatial web services, sharing of portlets across different spatial web portals, the flexibility and extensibility to develop new applications quickly and easily, and the communication among SWPs to sharing geospatial resources.

Interoperate Legacy Components Using Spatial Web Services

OGC has defined various specifications for spatial web services, such as the OGC Web Mapping Service (WMS; de La Beaujardiere, 2004), Web Coverage Service (WCS; Evans, 2003), Web Feature Service (WFS; Vretanos, 2002), Catalog Service for Web (CSW; Nebert and Whiteside, 2005), Portrayal services (WMS and WMS-SLD; Muller and MacGill, 2005), and Processing Services. The spatial web services are provided by middleware wrapping the legacy components to provide standardized interfaces. The spatial web services are then published in catalog services, where applications can find the services and bind the services needed to compose different clients for supporting specific business logics. The spatial web services provide interoperable interfaces for legacy components and extend the legacy components to be accessed/wrapped by portlets residing in a portlet container and accessed by web portal service.

JSR 168: Hosting Spatial Web Services

The portlets wrapping/accessing spatial web services are implemented through Java servlet and hosted by portlet container. When the portlet container and portal web service are residing on the same server, the communication between portal web service and portlet container is a series of local calls for web page fragments. The JSR 168/268 (Hepper, 2006) is used to facilitate the communication between portlets and a portlet container. Figure 2a shows the accessing sequence: (a) The client issues a request to the portal web service; (b)

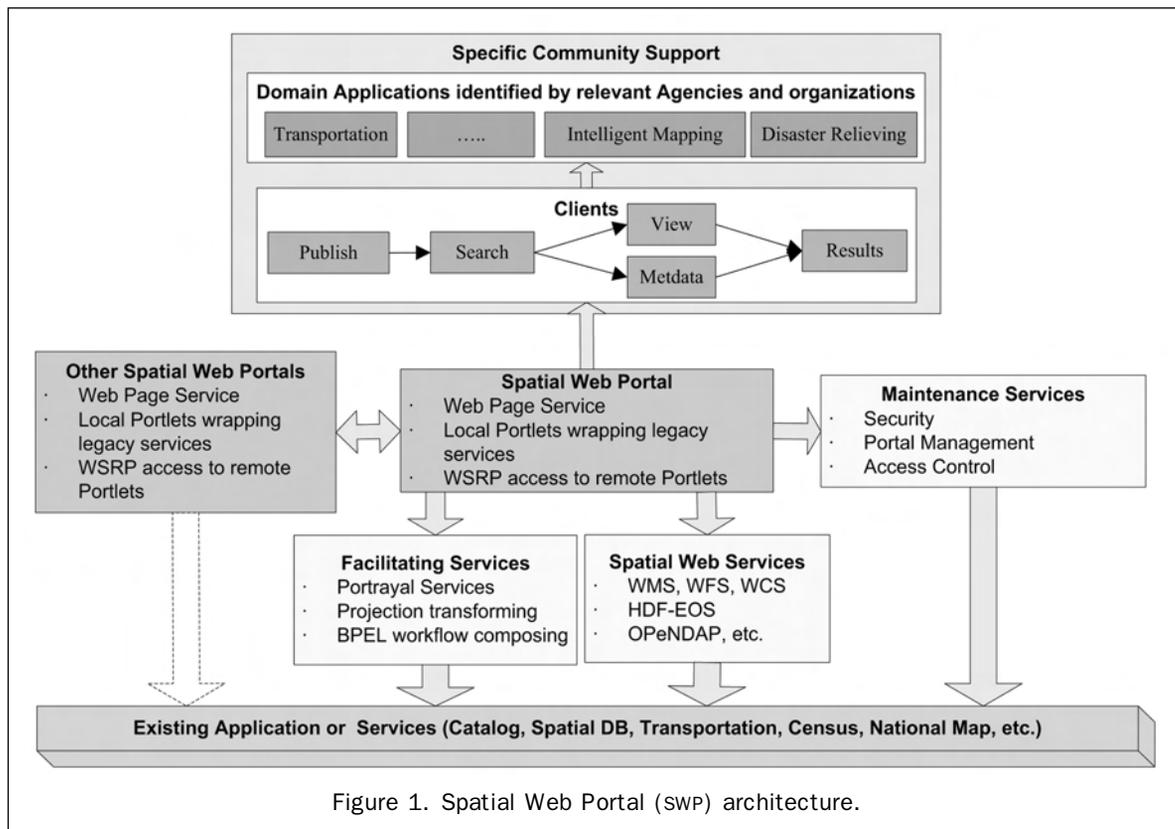


Figure 1. Spatial Web Portal (SWP) architecture.

the portal web service sends request to the portlet container; (c) the portlet container sends action requests to one or more portlets, and waits for them to take action such as updating a spatial database; (d) the portlet container sends render requests to portlets, to generate content fragments; (e) portlet container returns web fragments to the portal web service; (f)

which aggregates returned web fragments onto a portal page, and (g) which is returned to the client.

Sharing Among swps with Web Services for Remote Portlets (wsrp)

When a web portal service and a portlet container reside on different servers, WSRP is used to facilitate their communication.

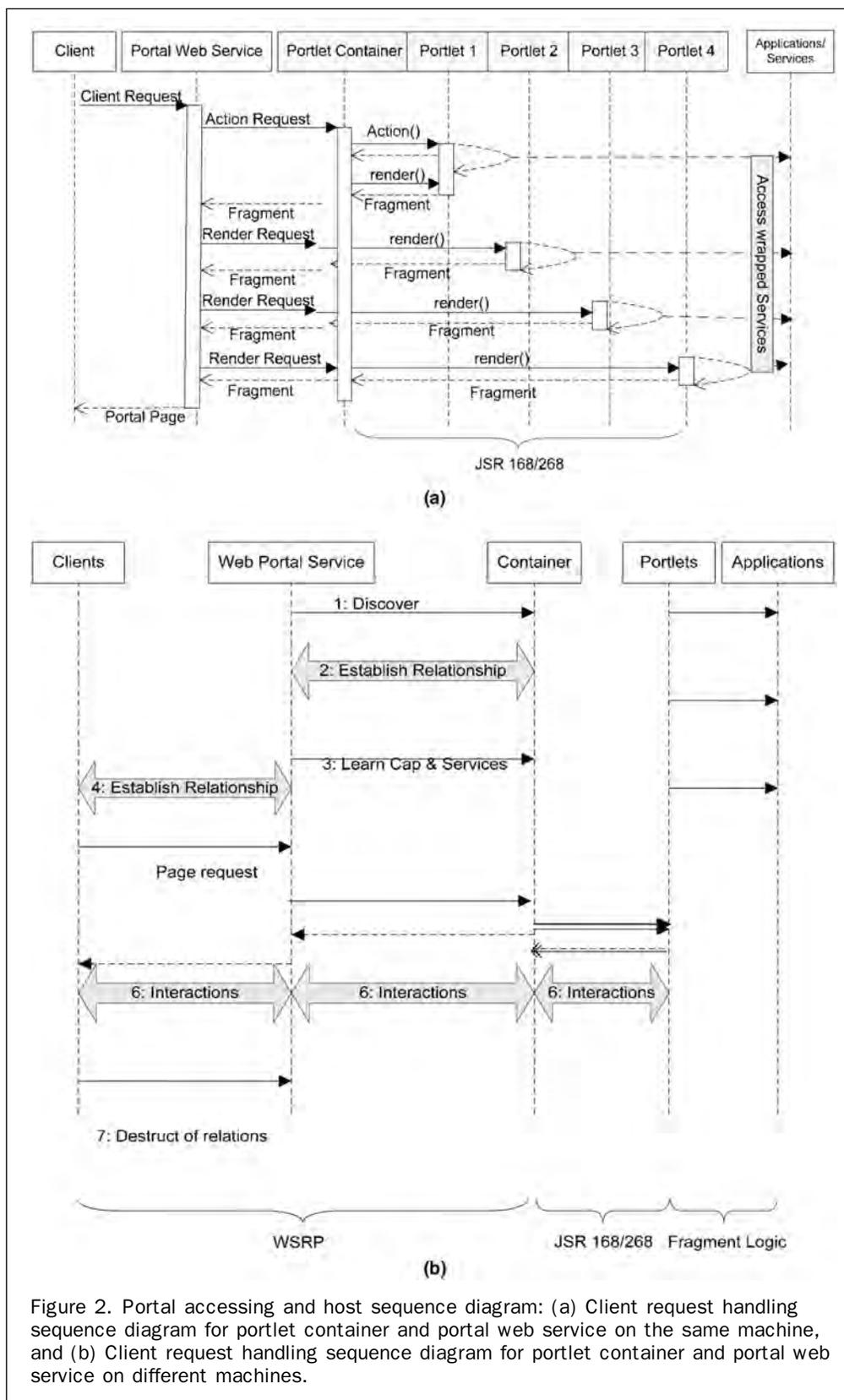


Figure 2. Portal accessing and host sequence diagram: (a) Client request handling sequence diagram for portlet container and portal web service on the same machine, and (b) Client request handling sequence diagram for portlet container and portal web service on different machines.

Figure 2b depicts the WSRP sequence (adapted from Thompson, 2006) aggregating remote portlets through web services: (a) the web portal service discovers an available portlet container; (b) an access relationship is established between the web portal service and the portlet container; (c) the web portal service obtains the capabilities of the container; When a user client accesses the web portal service, the portlet service (d) establishes a relationship with the client, authenticates the user; (e) and issues requests to the web portal service, which will issue requests to the container. The container then interacts with portlets through JSR 168/268 to get page fragments, and the web portal service aggregates them to return a web page; (f) further interactions among the components may occur upon subsequent user requests; and (g) the client ends the connection by destroying the relationship established with the web portal service.

The WSRP mechanism also supports sharing portlets among different SWPs, where different SWPs have different functions supported by portlets. This mechanism can help the construct of a spatial infrastructure using SWPs.

Web Portal

A portlet will access/wrap legacy applications, such as a GIS with functional components (Figure 3a), through the spatial web services and JSR168/268. Spatial Web Services can be added to the presentation layer of a typical application to share the output. The web services are then wrapped/ accessed by a portlet, which is hosted by a portlet container and accessed by a web portal.

A web portal is used to provide content aggregation from different sources and host the presentation layer of legacy Systems. Five parts of a web portal architecture is used (Figure 3b): (1) The client Graphical User Interface (GUI), such as a web browser, enables user interactions. (2) The web portal service aggregates contents produced by different portlets, either local or remote through WSRP. (3) The Portlet Container runs and manages Portlets, which process requests and generate content based on request from the portal, as defined by JSR 168/268. (4) The Security and Privacy layer provides application independent sign-in and other system protections. (5) Finally, information dissemination channels facilitate communication among all the components.

A portal web page is used to aggregate different portlet windows hosting contents encoded in web fragments. A portlet window can include other portlet windows, and has its own appearances and controls, such as maximize or minimize. Portlet windows are used as pluggable user interfaces that provide a presentation layer to backend applications or systems. For example, Figure 4 illustrates a portal web page aggregates a top portlet window with a banner and a "Welcome!" bar, and three portlet windows selectable through tabs as *Home*, *Find/View*, and *Browser*. The selected *Home* portlet includes five portlets entitled *My Account*, *Navigator*, *Life on Earth*, *Simple Search*, and *About*.

Within the proposed SWP, different heterogeneous geospatial resources, such as metadata, data, and services, are facilitated through relevant spatial web services, portlets, and integrated through web portal services according to application logic.

NASA's Earth Science Gateway (esg): An Example

NASA's ESG was designed as an implementation of the SWP architecture to support the sharing of NASA geoscience data and research results, and the developing of decision-supporting applications of national and global interest.

Figure 5 illustrates how the various components are implemented and deployed across different computers: (1) Application servers host applications and spatial web

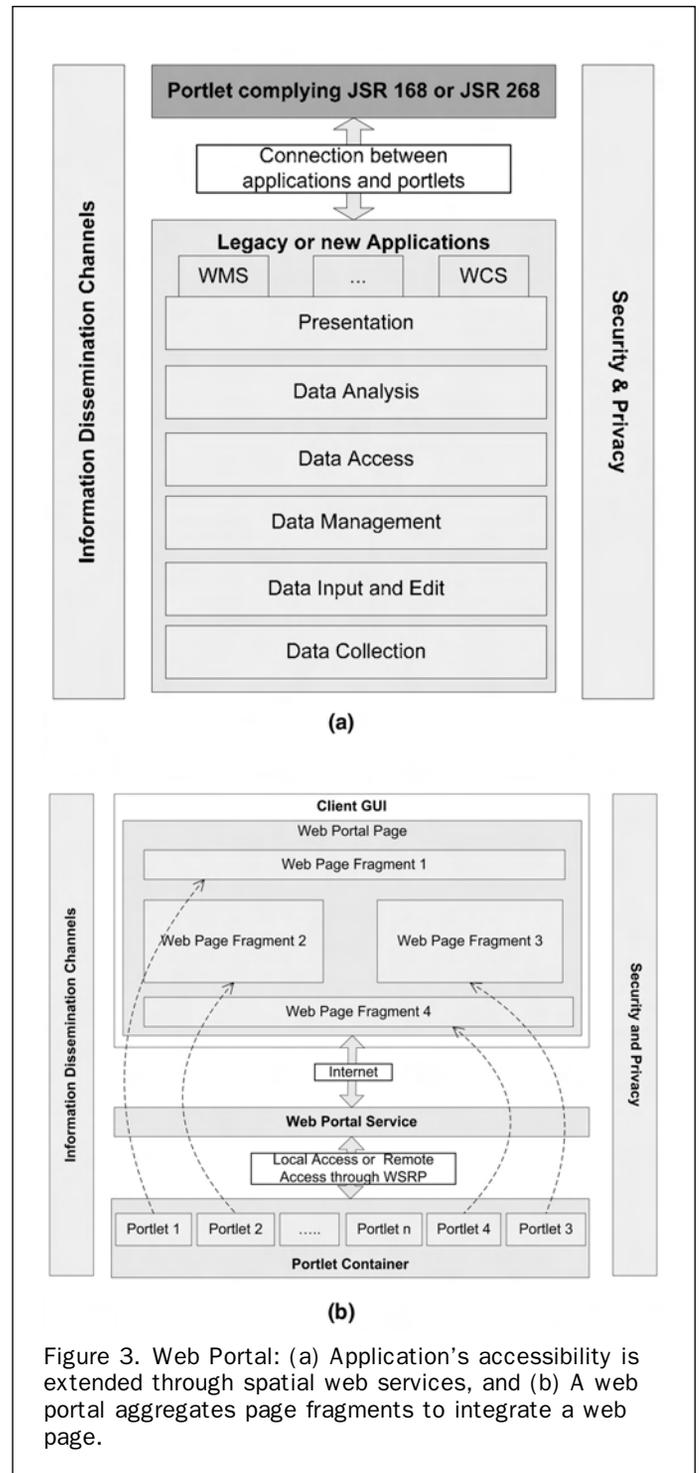


Figure 3. Web Portal: (a) Application's accessibility is extended through spatial web services, and (b) A web portal aggregates page fragments to integrate a web page.

services, the spatial web services are middleware implemented through either commercial software (such as ArcIMS[®]) or open source software (such as MapServer) according to application owner's preference. (2) Portlet servers host a portlet container, and web portal servers host Web Portal Service. The ESG portlet server and web portal server are based on Liferay, an open source software. ESG services are developed as Portlets using Java Servlet Technology. (3) At the client side, web development languages, such as HTML and Javascript, are used to develop web pages, which can be displayed within any web browser, such as Microsoft[®] Internet Explorer and Firefox.

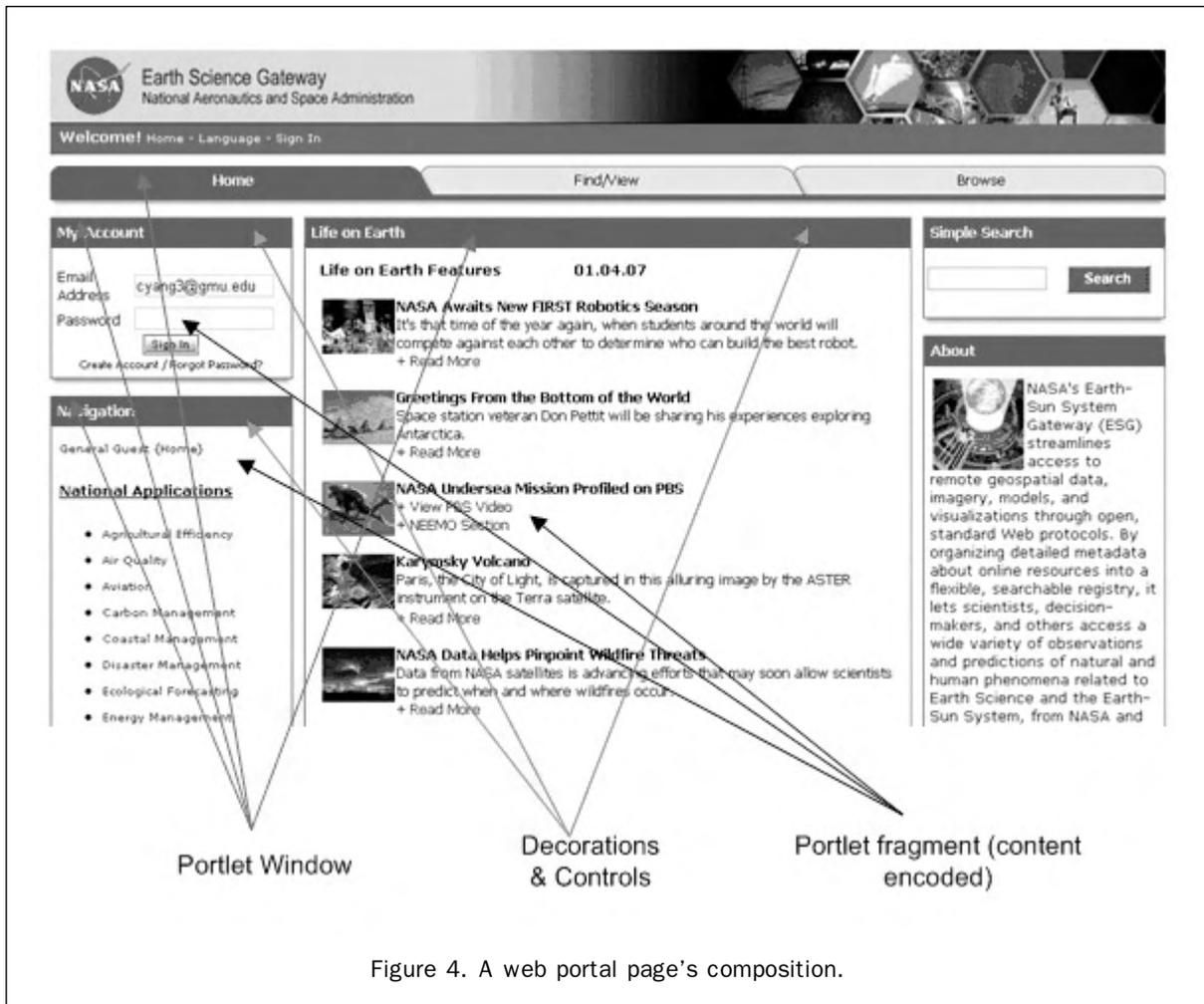


Figure 4. A web portal page's composition.

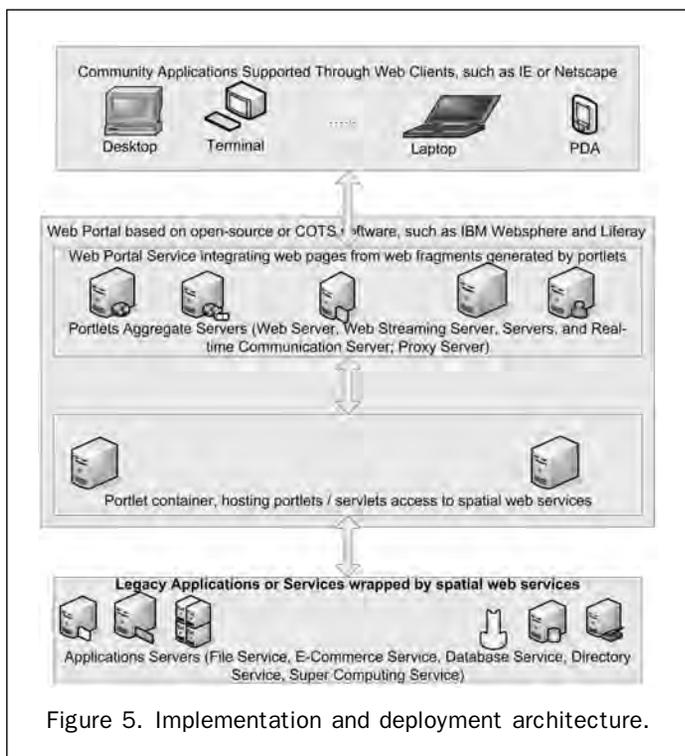


Figure 5. Implementation and deployment architecture.

Figure 6 illustrates the ESG logical architecture implementation based on the SWP: (a) the ESG Clients can be customized to support popular clients (such as Google Earth), National Applications and GEOSS applications (such as air quality and public health); (b) the clients are supported

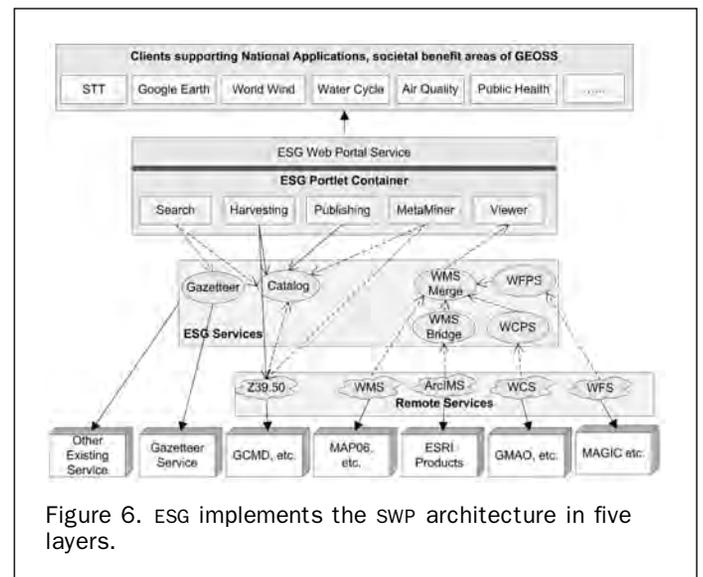


Figure 6. ESG implements the SWP architecture in five layers.

Publisher Wizard

The following table contains a list of content types that may be published in the Portal Repository. Select the type of content to be published from the list below and then click the **NEXT** button. Additional information about a Content Type may be obtained by selecting the Content Type name hyperlink.

Clicking the Harvesting Summary Status button will generate a summary/status report of items published during this session.

Metadata format to be associated with content being published: ISO19115

Select a Content Type

- [Web Map Service - OGC WMS](#) A Web Map Service with an OpenGIS Consortium Web Map Service interface
- [Web Feature Service - OGC WFS](#) A Web Feature Service with an OpenGIS Consortium Web Feature Service interface
- [Web Coverage Service - OGC WCS](#) A Web Coverage Service with an OpenGIS Consortium Web Coverage Service interface
- [Web Map Service - ArcIMS](#) An ESRI ArcIMS Map Service that will be exposed to the portal as an OpenGIS WMS through the portal provided OGC to ArcIMS connector
- [OGC Context Document](#) A OGC compliant context document containing metadata you wish to advertise.
- [Downloadable Data](#) Data such as GeoTIFF, Shape Files, VMAP, etc. or ZIP files that are available for download with a WWW URL.
- [Offline Data](#) Data such as GeoTIFF, Shape Files, VMAP, etc. or ZIP files that are only available by contacting the publisher (e.g., CDROMS)
- [Application](#) A service, application, web site that is accessible via a WWW URL.
- [Document](#) Information and metadata about a document or report that you wish to advertise

(a)

Content

Select one or more of the following to narrow your search:

- [Information Resource Type](#)
- [Topic Category](#)

Using search words:
(Separate multiple keywords by spaces)

Time:

Do not use date range

Before 2005 Jan 1

Between and 2005 Jan 1 2005 Jan 1

Location

Search for place name:

Choose a region: World Atlas

Placename:

Use Map Tools to define an Area of Interest

(b)

Find/View Welcome

Web Enterprise Suite

File Edit View Search Predefined Views Tools Help

Previous Next Stop Home Defach Search Favorites Print

Active Layer: Select Active Layer

(c)

Figure 7. The ESG Interfaces: (a) The ESG publishing page, (b) The ESG search page, and (c) The ESG Find/View page.

through the ESG web portal service, which aggregates the ESG Portlets from the ESG portlet container; (c) a number of portlets (such as search and viewer) access the ESG services (such as WFPS and Catalog); (d) the ESG services access the remote services through spatial web services specifications; and (e) these spatial web services wrapping earth observations (MODIS), atmospheric models (GMAO), a product Catalog (GCMD), and research results (MAP06) using middleware. The arrow links show the extract (upward) or update (downward) of data/information. Figure 4 provides an example of an aggregated web page from ESG. Figure 4 and Figure 7a through 7c show how ESG implements an SWP example and support different types of user interactions.

Figure 4 shows ESG's front page and main portlet, which aggregates basic geospatial information and operation portlets and provides a list of National Applications and NASA Science focused areas.

Figure 7a illustrates ESG's *publisher wizard* for ISO or FGDC standardized metadata for different resource types (such as applications, documents, WMS, WFS, and WCS) so that users can find them using a search interface. Figure 7b depicts the ESG search page aggregating spatial and non-spatial search functions. Figure 7c shows ESG Find/View page, which aggregates spatial web services from earth observation (such as MODIS), model simulation (such as CMAQ), and mapped images, to produce an SO₂ concentration for air quality and public health.

Through these functional pages and portlets, ESG supports interoperability of metadata, data, mapping, and other spatial web services.

In Figure 8, ESG connects/integrates NASA data services, catalog services, model services, and other scientific services to applications of national and international interest. The interoperable approach reduces long-term investment (Bambacus and Reichardt, 2006), and facilitates rapidly prototyping national applications and GEOSS applications (Birk *et al.*, 2006; CSC, 2006).

Conclusion and Discussion

We proposed a SWP architecture to facilitate geospatial components sharing and interoperability. As an example, we designed and implemented NASA's ESG to illustrate and test the architecture to interoperate heterogeneous geoscience resources.

The architecture provides a mechanism to integrate heterogeneous geoscience resources, such as documents,

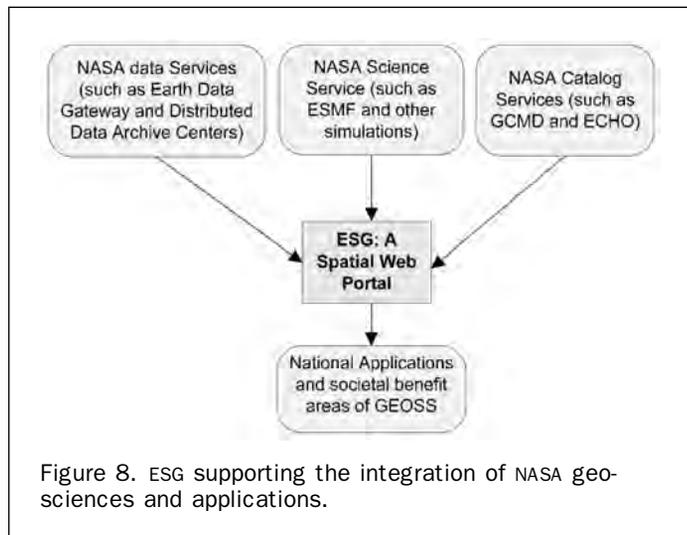


Figure 8. ESG supporting the integration of NASA geosciences and applications.

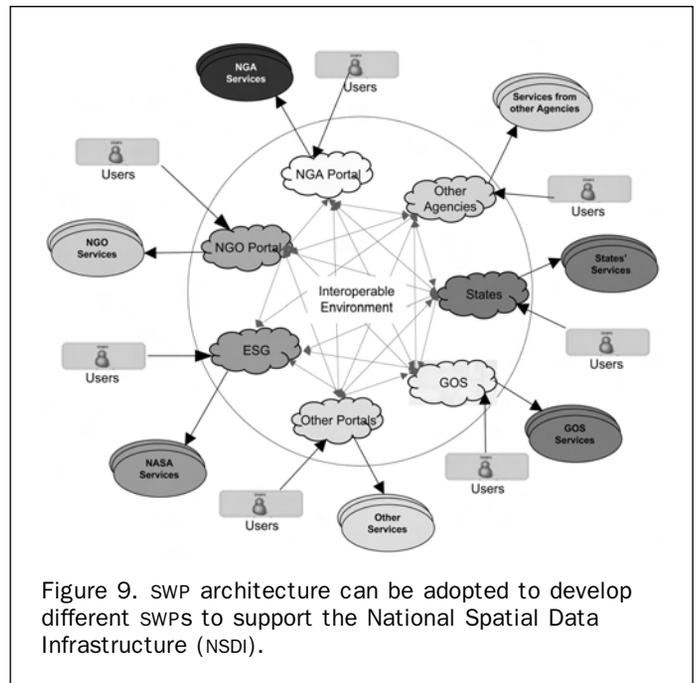


Figure 9. SWP architecture can be adopted to develop different SWPs to support the National Spatial Data Infrastructure (NSDI).

data, and services. For example, the earth observing data and metadata from various distributed Data Active Archive Centers (DAACs), OGC web services compliant model simulations, such as air quality, and other agencies decision support tools can be connected through ESG. At the same time, the architecture and system inherit the disadvantages of interoperability. For example, performance is impacted on transforming/integrating widely distributed resources, and research is also being conducted on supporting massive isolated services and simultaneous users (Yang *et al.*, 2005). It is also difficult to ensure the Quality of Services that may be required by different users ranges from the public to emergency managers. Also, the burden of the interoperability put on computing system and network bandwidth is significant when big volume of data is accessed. These are all areas needing further investigation.

We are utilizing ESG as a test bed to test new interoperability concept and research, for example, building a semantic search function based on SWEET (Raskin, 2005) and NOESIS (Ramachandran, 2005) to deal with ontology heterogeneity across different earth science domains. The ESG platform is also used for registering and sharing different geospatial resources in supporting GEOSS application demos and geoscience applications of national and international significance.

Furthermore, we are using the architecture and ESG as a reference and platform to implement the ESIP's Earth Information Exchange (EIE; ESIP, 2007) to ensure EIE can interoperate with other portals, such as the GOS portal, to support the National Spatial Data Infrastructure (NSDI; Figure 9), in which many different portals, each targets a particular audience community, can nonetheless work together by complying with a few key portal and geospatial standards. We are conducting ESG benchmark study to test the SWP's extensibility to general applications.

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