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Implementing Geospatial Web Services: A Resource Webliography

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Abstract

This paper is designed as a research tool for information specialists and science technology librarians seeking to build and understand geospatial web services (GWS). GWS permit users to dynamically access, exchange, deliver, and process geospatial data and products on the World Wide Web, no matter the platform or protocol. They are compliant with Open Geospatial Consortium (OGC) standards to advance interoperability. The paper briefly describes select GWS, OGC interoperability demonstrations, and software tools and applications that are fully or partly OGC compliant. Courses, cookbooks, and tutorials helpful to those seeking to build their own GWS are described. The use of GWS in geoportals is discussed briefly, particularly in those servicing spatial data infrastructures and scientific communities. Finally, challenges pertaining to the interoperability of GWS are noted in select publications and presentations.

Overview

Geospatial web services (GWS) help users find, access, and sometimes manipulate data of interest on the web dynamically from a distributed network. GWS are designed to collect data once and update or edit it in real time.

Many GIS users have not followed the development of tools and standards that facilitate the creation of dynamic GWS to access geospatial data and products. Yet non-experts already are deploying GWS built for SDIs (Fischer 2009). This article seeks to briefly describe select geospatial web services and to introduce the reader to a selection of demonstrations and tools enabling GWS interoperability. It describes tools and resources useful for those seeking to build their own geospatial services.

The GWS implementations, whether for geovisualizations, spatial analysis, mobile, or geogrid options, are being enhanced by collaborations with regional and global consortiums (e.g., Open Geospatial Consortium (OGC), Open Source Geospatial Foundation (OSGeo), Open Grid Forum (OGF)), national agencies, and industries. OGC collaborates with a broad spectrum of users. Many tools used to provide GWS functionality are described as are the geoportals that service spatial data infrastructure (SDI) initiatives, and scientific and social science communities.

Despite the success of the OGC, some challenges remain. In some cases geospatial web services are insufficient to deliver the functionality adequate for the secure and rapid exchange of large data sets. Google is very popular but largely non-standards adherent. OGC WMS services do not scale well, although a tiled WMS is expected in the next release. OGC's discussion papers mention aspects of web services or encodings that could be improved in the next releases. Janowicz, et al. (2009) suggest that an OGC transparent Semantic Enablement Layer (SEL) is needed for SDIs to enable the resolution of complex queries and to integrate heterogeneous information. Not all challenges are of the OGC's making. Almirall, Bergada, & Ros (2008) point out several shortcomings pertinent especially for SDIs: 1) the data lack timeliness, availability, reliability, or relevance, 2) opportunities are not exploited due to poor coordination or staff shortages, 3) difficulties present themselves in translating data into information relevant for policies, and 4) systems remain fragmented.

The OGC has been vigorously partnering with other collaboratives to provide better toolsets to communities still seeking to enhance interoperability and dynamic access to resources and analyses of interest. For instance, the AECOO-1 Testbed initiative (http://www.opengeospatial.org/pub/www/aecoo-1/index.html) was co-sponsored by the buildingSMART alliance. The Climate Challenge-Integration Plugfest-2009 (http://www.opengeospatial.org/projects/initiatives/ccip2009) was launched at the international FOSS4G Conference. The "Geo-interface for Atmosphere, Land, Earth, and Ocean netCDF" (GALEON) Interoperability Experiment (http://www.opengeospatial.org/projects/initiatives/galeonie) was initiated by Unidata/UCAR, IMAA-CNR, George Mason University and NASA.

Most of the e-resources selected for this webliography have been created or published on the Internet by OGC members, renowned organizations, or researchers within the last three years. The resources are meant to be representative of developments and research topics in the field.

The resources have been organized into eight sections:

6. Geoportals
7. Build Your Own Solutions
8. Journals/Presentations

Resources are arranged by topic category, although some resources cover more than one topic. Each resource is annotated to include details pertaining to scope, special features, challenges, and creator affiliation.

OGC Standards & Specifications: A Brief Description

Several OGC standards and specifications are briefly presented to describe the scope of the web geospatial mapping, analysis and data exchange. They are arranged alphabetically after the Reference Model (http://www.opengeospatial.org/standards/orm) that describes the relationships of OGC's baseline products that consist of abstract and implementation standards.

Within OGC's Reference Model (ORM), interface, encoding, profile and application schema standards are described and their relationships noted. Best practice documents are mentioned. The user is provided with an outline and details of the workings of OGC. Multi-tiered architectures are described that show how a service or component is organized within one of four tiers. The Sensor Web Enablement Architecture, and workflow and service chaining processed are diagrammed. Portals and Clients are described as providing users a means to access the web. Encodings, such as KML and GeoRSS, are designed to bridge the barrier between OGC services and non-OGC compliant ones.

In ORM, several OGC web services are detailed including the Web Map Service (WMS), the Web Feature Service (WFS), and the Web Coverage Service (WCS). The WMS makes visualizations of products produced using the WFS and WCS. The Web Processing Service implementation specification defines an interface that permits clients to find and bind processes. The processes supported, whether simple or complex, may include a calculation, an algorithm or model. WPS is critical to grid-enabled geospatial web services. Another key standard is the Catalogue Service standard, which is implemented widely to facilitate interoperability.

The OGC Catalogue Services interface for the web (CS-W) provides the user an opportunity to discover, browse and query metadata of either data or services (e.g., workflows). Its functions complement those of a registry's. The CS-W discovery manager interface uses GetCapabilities, GetRecords, and DescribeRecords operations. The CS-W publication manager interface uses Harvest and Transaction operations. CS-W uses a base metadata profile and an HTTP protocol binding. A registry is a service or component that manages catalogs and registers (Lieberman 2008). Registers store metadata semantics and representations.

CityGML is the OGC Encoding Standard for representing, storing and exchanging virtual 3D city and landscape models (http://www.opengeospatial.org/standards/citygml). It addresses the semantics and formats of complex and 3D data.

The OGC Filter Encoding standard (FES) defines an XML encoding for users to constrain or filter the set of features retrieved bases on spatial, temporal or scalar properties (http://www.opengeospatial.org/standards/filter).

The OGC Geography Markup Language (GML) provides the encoding specification for geospatial data in XML for the storage, transport, processing, and transport of geospatial features and schemas (http://www.opengeospatial.org/standards/gml).

OGC Grid Coverage Service implementation specification defines methods for vendors to relate raster analysis and processing (http://www.opengeospatial.org/standards/gc). Grid coverages refer to such objects as digital elevation models, satellite images, and digital aerial photographs where each ground coordinate represented in an image has an assigned data value or values.

An OGC implementation standard of KML version 2.2 (an XML language) is designed to provide broader implementation and interoperability of data presented in earth browsers. Further development is expected to harmonize KML with GML (http://www.opengeospatial.org/standards/kml).

OGC Open Location Services (OpenLS) interface standard provides interfaces for companies to represent applications involving such things as geocoding, mobile field service, proximity service and emergency response (http://www.opengeospatial.org/standards/ols).

In the OGC suite of Sensor Web Enablement (SWE) standards (http://www.opengeospatial.org/pressroom/papers). The Sensor Observation Service interface standard (http://www.opengeospatial.org/standards/sos). provides vendors with an API for managing and retrieving observation data An interface standard for querying sensor capabilities and tasks is provided in the OGC Sensor Planning Service (SPS) (http://www.opengeospatial.org/standards/sps).

The OGC Simple Features Interface Standard (SFS) provides a common method to developers for the storage and access of points, lines and polygons in databases, whether relational or object-oriented (http://www.opengeospatial.org/standards/sfa).

An OGC encoding profile that extends the WMS standard is the Styled Layer Descriptor (SLD). The profile permits the user to define symbols and coloring of features (http://www.opengeospatial.org/standards/sld).

The OGC Web Coverage Service (WCS) interface standard enables interoperable access to geospatial coverages, be they collections of features within a spatiotemporal domain, or a set of pixels depicting content from remote sensing imagery (http://www.opengeospatial.org/standards/wcs). Robin, Giacobbo, and Smolders (2007) have produced a helpful presentation of WCS pertaining to Earth observation.

The Web Feature Service (WFS) interface standard uses the HTTP interface for retrieving data access and manipulation operations for complex geospatial features. Users are thereby able to create, delete, update, or lock a feature instance. They also may query features (http://www.opengeospatial.org/standards/wfs).

OGC's Web Map Service (WMS) is the most heavily used service interface standard. It uses an HTTP interface to specify the layers, image format and user's area of interest to retrieve georeferenced images from distributed networks (http://www.opengeospatial.org/standards/wms).

OGC Interoperability Programs

Open Geospatial Consortium (OGC): OGC Web Services- Phase 4 (OWS-4) http://www.opengeospatial.org/projects/initiatives/ows-4

OWS-4 helped stimulate the rapid development of specifications important to enhance interoperability. The interactive demonstration videos it produced, available through the OWS-4 Demonstration hyperlink, are excellent. Over 72 organizations helped test a variety of services, including Web Coverage Service (WCS), Feature Portrayal Service (FPS), Sensor Observation Service (SOS), Sensor Planning Service (SPS), JPEG 2000 Interactive Protocol (JPIP), and GeoRSS (Reed 2006). Progress made by the initiative includes work on sensor web enablement, geoprocessing workflow, geo-decision support, geo-digital rights management, CAD/GIS/BIM, OGC location services and compliance testing. See details in the Testbed Summary document. Another fabulous video of work completed under OWS-4 is presented in the Space Time Toolkit described later by the University of Alabama.

OGC: OGC Web Services, Phase 5 (OWS-5)
http://www.opengeospatial.org/projects/initiatives/ows-5

The OWS-5 interoperability initiative resulted in a summary document and several excellent video demonstrations produced with the collaboration of 35 participating organizations. George Mason University, Intergraph, and Galdos helped develop the Sensor Web Enablement (SWE) workflow, workflow architecture and conflation test, and KML mashup, respectively. OWS-5 tested SOAP and Web Service Definition Language (WSDL) bindings, Business Process Execution Language (BPEL) scripts for service chaining, geo-decision support, compliance test scripts, and use cases demonstrating WCPS feasilibity.

OGC: OGC Web Services, Phase 6 Demonstration (OWS-6)
http://www.opengeospatial.org/pub/www/ows6/index.html

OWS_6 has focused on several threads: Sensor Web Enablement (SWE), Geo Processing Workflow, Aeronautical Information Management, Decision Support Services, and Compliance and Interoperability Test and Evaluation (CITE). Each of the threads is highlighted in an interactive demonstration video. Within the geoprocessing workflow thread, scenes 2 and 3 are extremely well done.

OGC Network: *Group on Earth Observations* (GEOSS)
http://www.ogcnetwork.net/pub/ogcnetwork/GEOSS/AIP2/index.html

Global Earth Observation System of Systems (GEOSS) is an effort to build an architecture to study socio-environmental themes: disasters, health, energy, climate, water, weather, ecosystems, agriculture and biodiversity. This demonstration video displays the use of WMS, WFS, WCS, SWE and GML. Some of the software used in the GEOSS pilots includes viewers such as such as ArcGIS Explorer, Google Earth, Gaia, uDig, and gvSIG that accommodate HTML, CSS or Javascript. Other tools included PostGIS/PostgreSQL, DB2 and Oracle Spatial. Particularly noteworthy in the video is the link for "Geoprocessing Services". Three interfaces were built for Phase 2 by the providers Environmental Systems Research Institute (ESRI) (http://geoss.esri.com/geoportal/catalog/main/home.page), European Space Agency/Food and Agriculture Organization (ESA/FAO), (http://www.geoportal.org/web/guest/geo_home), and Compusult (http://www.geowebportal.org/).

Geospatial Web Services by Type

Mention is made at times to reference and compliant implementations of OGC standards. Reference implementations are fully functional, and ones against which others are evaluated. A compliant implementation of a standard pertains to server-side software, and is considered to be fully functional as tested. The implementation can be considered, but not guaranteed, to interoperate with other properly implemented OGC standard products.

Web Map Services (WMS)

WMS provide users with a means to serve georeferenced maps available from a GIS server over the web. Servers using the WMS 1.0 implementation produce a map, answer basic queries, and communicate their functionality to other programs through GetMap, GetFeatureInfo and GetCapabilities interfaces. Via the GetFeatureInfo interface, users can retrieve attribute info pertaining to a mapped feature. WMS are implemented in over 280 products. If users request maps with the same bounding box, spatial reference system, and output size, they may produce a composite map built from sources located across a distributed WMS network. Where earth observations are requested, a WMS metadata model is required. When large or frequent map requests are made of a server, map caching may be slow. To work around the performance issue, pre-rendered images, or tiles, may be used (as in Google Maps) to speed the retrieval of WMS requests relating to Earth observation.

There are two reference implementations of WMS, versions 1.1.1, the official reference implementation, and 1.3, the candidate implementation. A reference implementation, compliant with an OGC specification, is one to which other developers evaluate their implementations. At least fifty products are compliant with WMS 1.1.1 and nineteen with WMS v. 1.3.0.

deegree: deegree 2.3 rc2
http://www.lat-lon.de/latlon/portal/media-type/html/language/en/user/anon/page/default.psml/js_pane/produkte%2Csub_produkte_deegree-services

lat/lon, through its deegree WMS, provided the reference implementations of WMS, versions 1.1.1 and 1.3.0. Its WMS implementation renders maps on-demand using standardized styling rules. deegree is the free modular Java web client framework maintained by lat/long GmBH and the University of Bonn. Its WMS uses all the data formats that its WFS and WCS support, including vector and raster formats and spatially enabled databases, as PostgreSQLl/PostGIS. It also transforms hundreds of coordinate reference systems on the fly. More product information is provided through PDF hyperlinks. Among open solutions, deegree probably represents the most robust implementation of OGC and ISO standards.

Cadcorp: Cadcorp GeognoSIS
http://www.cadcorp.com/products_geographical_information_systems/web_based_gis.htm

Cadcorp is a commercial U.K. GIS software developer built using Windows and ActiveX environments. Its GeognoSIS server compliant WMS 1.1.1 interface accesses over 160 data formats needing no further translation. The *Web Mapping in Action* hyperlink permits users to view the power of WMS interfaces. The University of Connecticut's Maps Online example uses CadCorp's WMS to display a number of aerial mosaics with a variety of vector lines superimposed.

Compusult: Web Enterprise Suite (WES) Analyst
http://www.webenterprisesuite.com/web/guest/wesanalyst

Web Enterprise Suite XI (WES portal) is an access portal for the Canadian Geospatial Data Infrastructure (CGDI) (http://www.geoconnections.org/en/aboutGeo.html) built by Compusult. Compusult, a Canadian computer service provider, built an interface for the GEOSS Phase 2 pilot mentioned earlier. WES Analyst, a module of the WES portal, provides dynamic web mapping using a middleware server to translate all requested map layers from distributed sources to the requested projection. It contains several components including WMS Merge, WFPS, Product WMS, and WMS Bridge. The OGC Web Feature Portrayal Service permits users to reveal WFS geospatial content in WMS layers, and clients to connect to WFS using a WMS request. Product WMS renders objects in XML or GML, and WMS Bridge helps portals and clients connect to ESRI's ArcIMS Servers.

CubeWerx: Announcing CubeWerx Suite 4.12
http://www.cubewerx.com/

CubeWerx provides a powerful suite of geospatial Web services and data warehousing products. Its Cascading Web Map Server cascades other downstream servers to provide developers with a unique common interface. Its interface enables several data sources to be seamlessly translated and overlaid. The Cascading WMS Demo in Google Earth (http://www.cubewerx.com/demos/cascading) seamlessly translates data from several clearinghouses using a Java API, and a Google Earth Extension for WMS 1.0 (http://www.opengeospatial.org/resource/products/details/?pid=620). Other CubeWerx tools include a Web Map Tile Server (WMTS), a WFS that eliminates proprietary interfaces, and a powerful security framework, all described through the "Products" tab.

Web Coverage Services (WCS)

WCS, OGC's raster service standard, retrieves "coverages" or geospatial information pertaining to multidimensional phenomenon at points in space that vary across geographic region. Each WCS provides access to simple or "grid coverage" information via three operations: GetCapabilities, DescribeCoverage, and GetCoverage. The information (available data and metadata), although not displayed by WCS, may be portrayed by WMS, used in multi-valued coverages, or used in scientific models. Its functionality facilitates the subsetting, scaling, reprojection, and format encoding of grid data. When operation requests are made using XML they may be encapsulated within a SOAP envelope. The anticipated WCS 2.0 will rely on the GML coverage model. WCS extensions include WCPS (described below) and WCS-T. WCS-T is a transactional service operation that can add, modify, or delete grid coverages from a WCS server while providing the updated coverage metadata (http://www.opengeospatial.org/standards/wcs).

Environmental Systems Research Institute (ESRI): ArcInfo: The Complete Desktop GIS

http://www.esri.com/software/arcgis/arcinfo/index.html

ESRI is a long-standing leader in GIS desktop, server, and web services development. The desktop ArcGIS v. 9.3 has implemented three versions of WCS (v.1.1.1 c1, v.1.1.0, and v.1.0), so that professionals may manage and analyze raster content after adding a WCS Server connection. ArcGIS Desktop serves as a WCS client and may use the raw data in a raster geoprocessing model, or to generate a surface. Raster datasets may be exported in several formats including GeoTIFF, JPEG, JPEG2000, and PNG. Note its use to model slopes in the video *Using ModelBuilder to Perform Geoprocessing and Analysis*, available through the "Demos" hyperlink. Through the "Support" tab instructions on how to add a WCS service layer in ArcMap are given.

ESRI: ArcGIS Server

http://www.esri.com/software/arcgis/arcgisserver/index.html

ESRI's ArcGIS Server 9.3 provides advanced and distributed functionality and adherence to OGC standards, as demonstrated in its GEOSS portal, mentioned earlier. ArcGIS Server's WCS 1.0.0 is a compliant OGC implementation. ArcGIS Server may publish the geoprocessing models it consumes as a WCS 1.0, 1.1 or 1.1.1 service. It also performs the functions of ArcGIS Desktop as described above.

GeoServer: Welcome

http://geoserver.org/display/GEOS/Welcome

GeoServer is a free and very reliable Java-based open source software server which developed the reference implementation of OGC's WCS 1.0/1.1. As noted in a FAQ of its blog, many would like to enhance GeoServers's WCS capabilities for 3D and 4D data. Its WCS 1.0 has several strengths including the publication of multidimensional gridded data, but an identified weakness pertains to OGC restrictions on Coordinate Reference Systems (CRS) addressing. Geoservers's WCS functionality is described in the User Manual available through the Documentation tab. Testing options for its WCS are available through the Developer Manual.

Web Coverage Processing Services (WCPS)

WCPS is an extension of the WCS v. 1.1.2 and is based on the WCPS language interface standard (http://www.opengeospatial.org/standards/wcps).The protocol-independent language permits processing requests of "coverages" or multi-dimensional digital geospatial information that varies spatially and/or temporally. It enables the, extraction, processing, and analysis functions pertaining to the sensor, image and statistics data represented by coverages. It is thought to bridge WCS and WPS. Since WCS are limited to quadrilateral coverages, multi-dimensional data is available at the grid points. Interpolation may provide data between the grid points. Petascope (http://www.petascope.org) is the reference implementation of WCPS.

Jacobs University Bremen: Earthlook
http://www.earthlook.de/

Jacobs University has supported several projects of interest to OGC and INSPIRE members pertaining to Earth observation. It maintains projects involving interfaces and products to support access to large-scale data sets from sensors. Earthlook is such a project. A video of the project, found under the August 2009 entry, should be downloaded to ensure proper viewing. It demonstrates NASA's experiment with WCPS, a flexible processing extension of WCS that delivers fast raster services. Other great demonstrations are available by following the hyperlink "demonstrate and showcase" to the subsequent "special demo track" hyperlink. Earthlook has been produced using relational databases, developed as a raster data manager in collaboration with rasdaman.org.

Web Feature Services (WFS)

The WFS interface permits users to access and manipulate geospatial feature information from distributed network sources. Basic operations include GetCapabilities, DescribeFeatureType and GetFeature operations. More complex operations are available through the WFS-T service interface described below.

Intergraph: GeoMedia
http://www.intergraph.com/sgi/products/productFamily.aspx?family=10&country

Intergraph is a leading GIS and engineering software. GeoMedia WebMap Professional 5.01 provides an OGC server compliant WFS v. 1.0.0. and implements WFS-T 1.0.0. GeoMedia's 6.1.5 "SDI Pro" version supports a Gazetteer Service, a transactional WFS, and a secured WFS (Sonea 2008). GeoMedia reads many data formats without translation, and its WFS are able to capture changed features via a thin client.

Web Feature Services- Transactional (WFS-T)

WFS-T interfaces permit the user to create (insert), delete, update and lock feature instances, and retrieve or query features. The interfaces are written in XML, while GML is used to describe the features within the interface. So that transactions may be properly stored in a datastore (e.g., SQL RDBMS), transaction semantics are applied.

ERDAS: ERDAS APOLLO Server
http://www.erdas.com/tabid/84/currentid/1985/default.aspx

ERDAS' APOLLO Server, a core module of the APOLLO SDI solution, manages vector and image workflows. Through its "Demo" folder, transactional WFS are demonstrated in a video "Remotely Filter and Edit of Vector Data [sic]." ERDAS also supports WFS-G. ERDAS Enterprise Wikimapia Solutions Paper wiki (http://www.erdas.com/LinkClick.aspx?fileticket=XZ8n%2Fix1u28%3D&tabid=132&mid=540) indicates that the workflow of WFS-T can be augmented by Oracle Workspace Manager.

Web Processing Services (WPS)

WPS seem to offer users an unlimited capability to build and facilitate the publication of geoprocessing tools for vector and raster data. Implementations may be considered middleware. Here processes pertain to calculations, algorithms or models involving georeferenced data. In publishing, binding information and metadata are made available to facilitate discovery and access. For interoperability, standards for application profiles for each process are offered. Users finding a WPS service may input data and execute the process without knowing about the interface or application profile. WPS provides for both platform-neutral and platform-specific specifications. WPS uses DescribeProcess and Execute operations for encoding requests and responses, embedding data and metadata, referencing inputs and outputs, and requesting storage of outputs. The construction of repeatable workflows is possible with WPS through an orchestration of service chains, calling a sequence of web services, or via simple service chains. Moreover WPS is compatible with WSDL and SOAP, and may add security certificates. Its advantage over current WSDL/SOAP specifications includes its ability to specify output storage, its facilitation of service chaining, and its flexibility for use by REST or SOAP architectures.

52North: 52n WPS
http://52north.org/maven/project-sites/wps/52n-wps-webapp/

> 52north is a German nonprofit group managed associated that develops open source geospatial software. 52North WPS uses Java in an open source implementation to provide a pluggable framework to orchestrate and execute geoprocesses. 52North's WPS supports GeoTiff, ArcGrid, and GML2 data types, while its invocation exposes a WSDL document important to some developers for the gridification of GWS WPS instance using uDig client is demonstrated via the "Demo Theater" link. Although the download may be slow, it is well worth the wait. In a prototype to support the orchestration of Grid-enabled GWS, 52Norh"s WPS offered algorithms for buffering and geometry simplification (Hobona et al. 2009).

Wald.Intevation: Welcome to PyWPS
http://pywps.wald.intevation.org/

> PyWPS (Python Web Processing Service) is supported by Wald-Intevation while the site is maintained by HS-RS. PyWPS implements the OGC WPS standard. It offers native support for GRASS GIS and supports a generic WPS Java Script library. Still PyWPS works well without GRASS GIS and is available for download. Through a "Documentation" tab, the user may access installation instructions and the "Gallery", a wiki which shows sites under development. PyWPS has been use very effectively with Google Earth for accelerating geospatial data archiving and distribution using the GridJet protocol (Wang et al. 2009).

Sensor Web Enablement (SWE) Architecture

Several OGC interface, model and encoding specifications have been adopted to facilitate real time integration of sensor data into information infrastructures. SWE strives for Internet sensors to be available and controllable via the web, if appropriate (SWE Overview and High Level Architecture 2007). All specifications fit within an architectural design. They include Observations & Measurements (O&M), Sensor

Model Language (SensorML), Transducer Model Language (TML), Sensor Observations and Service (SOS), and Sensor Planning Service (SPS). Others await final adoption, and include Sensor Alert Service (SAS) and Web Notification Service (WNS). The specifications are designed to permit users to fuse sensor data with other geospatial data. In SensorML processes and processing components are defined, including an executable process chain. Sensing platforms include ground stations, land, air and water vehicles, water buoys, and people. In SOS core operations include GetObservation, DescribeSensor and GetCapabilities. SPS provides specifications for collection, requirements, mission, and asset management, and collection management process. TML specifies a standard for a communication protocol to exchange archived or live streaming data. It describes sensor data, the sensor system, and physical and semantic relationships.

52North: OX-Framework
http://52north.org/maven/project-sites/swe/oxf/index.html

> 52North's OWS Access Framework (OX-Framework) provides developers a way to extend and customize a variety of thin, thick or mobile clients. The OX-Framework Rich Client implements several OGC specifications including Sensor Planning Service (SPS), Sensor Observation Service (SOS), and Sensor Alert Service (SAS) via a service-connector component. Several OX-F swing clients' videos have been made available through the "Demos" hyperlink at "Rich OX-Client (Videos)". The framework has been used as the technological basis for recent sensor web applications (Broering et al. 2009).

University of Alabama: Space Time Toolkit
http://vast.uah.edu/index.php?option=com_content&view=article&id=16:space-time-toolkit-overview&catid=14:overview&Itemid=55

> Space Time Toolkit (STT), developed by the University of Alabama, integrates spatially and temporally–disparate data using OGC data access standards. It helped develop the SWE Architecture. Among others these OGC standards are implemented: Sensor ML, SOS, SPS, and O&M. When the user requests the swath, map projection, station, event or path in a select spatial and temporal domain, the end user also may request the aggregation and resolution of the temporal domain in either a 2D or 3D display. A fantastic demo of the OWS-4 effort is available and referenced in a presentation by Botts (2008): (http://vast.uah.edu/downloads/videos/UAH-ows4-narrated.avi).

OpenGIS Location Services (OpenLS)

OpenLS is an interface standard that consists of a set of basic and more complex services. The core services include a directory service, a gateway service, a location utility service (to geocode and reverse geocode,), a presentation service, and a route service. The directory service helps subscribers access the nearest or specific place. The gateway service retrieves the location of a mobile terminal (device). More complex services include a navigation service and a tracking service. The navigation service is an enhanced route service and network accessible. The tracking service tracks a group of moving objects.

Pitney Bowes Business Insight: Envisa Online Services OnDemand Offering for Location Intelligence
http://www.pbinsight.com/products/location-intelligence/ondemand-offerings1/envinsa-online-services1/

PB Business Insight, formerly PB MapInfo, develops location intelligence and GIS Support. Through Envisa's "Resources" tab, two hyperlinks are available: "Industry Standards" and the demo "Envisa: miTrip Application" which provides the user access to an OpenGIS Location Service (OpenLS) service. The "Industry Standards" hyperlink describes Envisa's adherence to several OGC standards and specifications including GML 3.0, OLS 1.1, WMS 1.1.1 and WFS 1.0. Envisa's OpenLS interfaces and API permit users to customize tools for location intelligence appropriate for several endeavors including asset tracking, call centers and mobile applications.

More Tools, Software, and Platforms

Both commercial and free open source tools and software are described here. Many of the free open source tools and software do not have the comprehensive and robust toolsets developed by commercial providers. Yet the use of free open source tools in the OWS demos testifies to the power both of individual tools, and the open modular infrastructure as specified in the ORM by OGC.

Tools

Codehaus: GeoTools: Home
http://docs.codehaus.org/display/GEOTOOLS/Home

GeoTools is an open source Java GIS toolkit used for OGC based projects via GeoAPI interfaces. GeoTools implements the OGC Grid Coverage implementation, the Filter Encoding specification, the Simple Features Specification, GML, WFS, and WMS. A hyperlink to the GeoTools 2.6.x stable version, will lead the user to other hyperlinks, including a "Geospatial for Java Tutorial". Plug-ins have been built for shape files, ArcGrid, ArcSDE, PostGIS, Oracle Spatial, MySQL and many more tools.

Generalitat Valenciana: gvSIG
http://www.gvsig.org/web/home/gvsig-home/view?set_language=en

Generalitat Valenciana serves the city of Valencia. Its GIS tool, gvSIG, implements OGC standards and specifications including CS-W, Filter Encoding, Gazetteer Service Profile, WCS, and WMS. It supports mobile and desktop platforms and ESRI's ArcIMS and ArcSDE clients for 3D, LiDAR, and mobile interoperability. Downloads, documentation, courses and tutorials are provided through hyperlinks.

OpenLayers: Free Maps for the Web
http://www.openlayers.org/

OpenLayers is an open source JavaScript library that uses a JavaScript API to build free geospatial web client applications. It implements WMS and WFS, and handles GeoRSS feeds for map display (Turton & Murdoch 2008). Its WFS-T works well in tandem with GeoServer. Its framework was designed so that map tools may operate on all map data sources, avoiding the pitfall of proprietary silos. The site provides access to its wiki, blog and downloads through tabs. Impressive implementations may be viewed through the "Gallery" tab. See the

Long Island Index Interactive Map hyperlink, and that site's video tutorials, available through the "How do I..." tab.

Software

con terra: mapClient 2.3
http://www.sdi-suite.de/index_en.shtm

con terra is a German geospatial web services developer that manages sdi.suite which supports OGC, ISO and INSPIRE standards. The mapClient tool supports WMS, WFS, ArcGIS Server, and ArcIMS services. It integrates feature portrayal and editing services, as noted in the "Demo Tour (Flash)" link. MapClient's 3D icon offers users terrainViewer capabilities through the "Live Application" link. Additional sdi.suite tools such as serviceMonitor, securityManager and licenseManager support geoportals.

GeoNetwork Opensource
http://geonetwork-opensource.org/

GeoNetwork Opensource was developed by FAO, World Food Programme, the United Nations Environment Programme, and the UN Office for the coordination of Humanitarian Affairs. Its free open source application implements the portal and catalog components of OGC's Reference Architecture. Its portal services provide access control and a tool for advanced metadata editing. Its catalog services (CAT 1.1.1 and CAT CS-W 2.0.1) implement a metadata clearinghouse providing access to data and metadata. Its data services component permit data processing involving features and coverages and SLD maintenance through OGC encodings and interfaces.

Google: Google Earth Developer's Guide
http://code.google.com/apis/earth/documentation/

Google Earth, an extremely popular commercial 3D digital globe application, permits users to add WMS overlays. The Developer's Guide provides instructions to users wishing to embed Google Earth into web pages, and import and/or return KML representations of features. Tabs lead the user to the Google Geo Developers Blog. Users will find hyperlinks to documentation on KML and MapsAPI, and samples of code. Google's efforts to team with OGC have yielded an implementation standard abstract test suite of KML v. 2.2 (OGC, 2007c). CubeWerx has developed a Google Earth Extension for WMS (OGC 2008c). Still Google has few OGC compliant products, and many in the geospatial community are fearful that developers may stray from open geospatial standards making the future of open source development difficult.

GRASS: Welcome to GRASS GIS
http://grass.itc.it/

The Geographic Resources Analysis Support System (GRASS), an official project of OSGeo, is a free and powerful GIS and image processing and analysis software package. It is licensed under a GNU General Public License. Software downloads, manuals, a newsletter, and wiki are available through tabs. GRASS operates on Linux, MacOSX, and MS-Windows, and is WMS and WFS compliant. Several videos/tutorials on YouTube describe its functionality, including one: *Normalized Difference Vegetation Index with GRASS GIS* (http://www.gisuser.com/content/view/18221/2/). JGrass has been built using the uDig framework (see Refractions Research).

MapServer: About

http://mapserver.org/about.html#about

MapServer is a free application that supports several OGC standards (e.g., WMS, WCS, SLD, GML, SOS), thousands of projections, many raster and vector formats, advanced cartographic output, cross-platform support (Linux, Windows, Mac OS X, and Solaris) and several development tools, including PHP, Python, Perl, Java, .NET, and Ruby. See the entry for MapServer Tutorial in the Cookbooks/Tutorials section.

PCI Geomatics: Download Products and Features

http://www.pcigeomatics.com/index.php?option=com_content&view=article&id=91&Itemid=12

PCI Geomatics is a Canadian firm that develops Geomatica and associated geo-imaging solutions is an OGC strategic member. The site's hyperlinks to webinars, case studies, white papers, newspaper archive, and articles detail Geomatica's powerful capabilities for geospatial analysis and modeling functions that implement OGC standards. In the GEOSS program, Geomatica implemented a still to be adopted specification, the Web Coordinate Transformation Service (WCTS), to access coordinate transformation services. Pluggable functions are available from its developer toolkit for those interested in developing applications on the fly. In the "Download Product Animations Now!" section, the user may view an impressive demonstration of a statistical overlay.

Refractions Research Inc.: uDig

http://udig.refractions.net/

uDig (user-friendly desktop Internet GIS) is a free Java open source desktop application made in conjunction with GeoTools that integrates databases, WFS, and WMS, GeoRSS, and KML. It provides support for TileServer through a cached WMS. It hopes to support a WCS implementation. Unlike ArcGIS Desktop, uDig runs on three software operating systems: Linux, Mac or Windows. Its framework is built with Eclipse Rich Client technology, which enables developers to extend its capability with "plug-ins" to perform complex analytical tasks. Note that it built JGrass on the uDig framework. Downloads and documentation for users and developers are available through tabs.

Refractions: What is PostGIS?

http://postgis.refractions.net/

Refractions Research developed PostGIS via its API to spatially enable the PostgreSQL database for GIS. PostGIS implements the OGC Simple Features specification for SQL. More robust support is anticipated for topology, raster, networks, networks, 3D, and geometry. A section named "Other links" informs users of software with which PostGIS has been integrated. The Documentation tab leads the use to a wiki, and a "Case studies" hyperlink, which highlights several map services. The "Downloads," "Support," and "News" tabs keep the user updated on software updates and capabilities.

Safe Software: FME Server Overview

http://www.safe.com/products/server/overview.php

Safe Software provides scalable and powerful capabilities for spatial data extraction, transformation, and loading (ETL) suitable for statewide and multinational endeavors. FME Server supports a very wide range of formats (see "Formats List"), and is used widely for its streaming and migration services. The FME Server has been used for its download and upload capabilities. Through the "Demos" link, view "Creating a Data Upload and Validation Service with FME Server", and the live Website North Dakota Hub Explorer, which uses the SpatialDirect version.

Snowflake Software: Publish to Open Standards with GO Publisher http://www.snowflakesoftware.co.uk/products/gopublisher/index.htm

Snowflake Software develops geospatial data exchange solutions involving SQL Server, PostGIS, Oracle, while adhering to OGC and INSPIRE guidelines. Several GO Publisher editions are available through tabs, including the WFS Edition. Its "Demonstrations" link, allows the user to view demos of GeoSciML, CityGML, and XML and GML using AIXM5 (Aeronautical Information Exchange Model) data. In the AIXM5 demo, a compressed encoded WFS URL is streamed on the fly to Google Earth via a network link.

University of Bonn: Heidelberg 3D in XNavigator
http://koenigstuhl.geog.uni-heidelberg.de/xnaviwiki/doku.php

The Cartography Research Group at the University of Bonn is recognized worldwide for its efforts to promote geospatial interoperability, including its work on geoprocessing workflow and decision support services in OWS-6. It builds and implements GDI3D, an extremely impressive 3D stand-alone solution fully based on OGC web services. Heidelberg-3D demonstrates the capability of XNavigator, the free viewer which uses Java web start technology. XNavigator presents 3D city models, route planning capabilities, and address retrieval. Links to software downloads, several very impressive videos, and publications are provided.

Platforms

The Carbon Project: Gaia Geospatial Platform
http://www.thecarbonproject.com/gaia.php

The Carbon Project is a consultant firm that focuses on geospatial interoperability. Its open Gaia 3 Viewer was built using the Carbon Tools PRO toolkit for geospatial network and SDI needs. The Viewer supports the seamless integration of multiple layers, proxy configurations, and password-protected OGC services. Within the platform several OGC services are supported, including WMS, WMTS, WCS, WFS, and FE. Users will find a link to a video tutorial that details support for GML, WMS, and WFS. Its extenders include those customized for Emergency Management Services, GPS, Secure SDI, and the US National Grid. Tools described through a "Products" tab, include Carbon CloudSync that synchronizes data stores, and a dashboard (a Web page with real time information) for Geodata.gov. See the demo movie, through links from the "Gadget for Geodata.Gov".

Open Source Geospatial Foundation (OSGeo): Home
http://mapguide.osgeo.org/features.html

OSGeo is a nonprofit organization that supports and promotes open source geospatial collaborations and software. The MapGuide Open Source platform it supports permits users to rapidly develop and implement applications using WMS and WFS services. MapGuide supports tiled map display via an AJAX viewer, feature buffering, and several geospatial files and database formats. Features from distributed data sources may be queried and updated using a variety of API tools, such as PHP, .NET, Java, and JavaScript. An interactive demo from the MapGuide live gallery hyperlink gives the user a chance to buffer features and more. Using MapGuide Open Source as a base, Autodesk built MapGuide Enterprise software in combination with an Autodesk authoring tool: MapGuide Studio (http://usa.autodesk.com/adsk/servlet/pc/index?id=6546938&siteID=123112).

Geoportals

Spatial Data Infrastructure (SDI) Portals

Geospatial web services play a large role in helping both SDIs and scientific communities share and analyze data important to manage disasters, building projects, environmental threats, etc. SDI portals and software promote interoperability when compatible versions of software are used. Exemplary SDIs have well developed implementations serving many organizations having multidisciplinary challenges. Note the Canadian Geospatial Data Infrastructure (http://www.geoconnections.org/en/aboutGeo.html). They use conforming standards and interfaces and stable software (Nebert, Reed and Wagner 2007). The best SDIs still need to work on developing high level architectures to define an interoperable framework of standards (Nebert, Reed and Wagner 2007). Some use new and old versions of standards. As suggested by Almirall, Bergada & Ros (2008), SDIs still are challenged to provide updated information, tools to broaden the use of metadata, and services and applications for local public administrators.

SDIs given the best practice commendations at a 2009 conference sponsored by eSDI-NET+ included those that implemented INSPIRE principles, provided a capability to others to extend or use the models, fostered cooperation, and used more than basic technologies. Among others, GDI Nordrhein-Westfalen was honored for its institutional and organizational aspects, Forth Valley GIS (UK) for its technological aspects, IDEC Infraestructura de Dades Espacials de Catalunya (Spain) for its focus on users, and Norway Digital-ND for its thematic SDI aspects. Links to other SDIs may be found at GSDI's Geographic Information Knowledge Network, with its depository of SDI/GIS best practices and case studies. SDI best practices are also outlined in a presentation *Evaluating SDI Best Practice* by Longhorn (2009).

The recommended minimum software standards suite for SDI changes as technologies and use advance. The latest recommendations are available in the SDI Cookbook, Chapter 10 described later. Currently the recommended suite includes: WMS, v. 1.3, WFS, v. 1.1 of WFS-T, FE v. 1.1, GML v. 3.2.1, KML, v. 2.2, WCS, v. 1.1.2 and CAT CS-W (2.0.2) or CAT2 ISO AP (2.0.2). Supplemental standards are also recommended.

European Commission: INSPIRE Geoportal
http://www.inspire-geoportal.eu/index.cfm/pageid/341

The INSPIRE Geoportal provides a WMS viewer, a registry containing an ISO 19135 compliant glossary and feature concept dictionary, and a metadata editor, which allows users to validate their metadata and to save it as an XML file. Its SOAP primer analyses the INSPIRE WSDL and compares its implementation with OGC recommendations. Other tools used to comply with EU directives include con terra's sdi-suite and FME Server by Safe Software. Although metadata and service access is limited in this prototype, INSPIRE plans to fully monitor and report on several SDI elements (accessibility of metadata, use and conformance of spatial data services, organization, coordination and quality assurance) (Longhorn 2009).

IDEC Infraestructura de Dades Espacials de Catalunya

http://www.geoportal-idec.net/geoportal/eng/inici.jsp?pag=home.jsp

Given a best practice award at a 2009 eSDI-NET+ conference for its focus on users, IDEC is the SDI of Catalonia. Its Support Center provides the policies, technologies, and standards enabling the storage, processing and distribution of geospatial information. IDEC supports more than one hundred ten organizations which have published metadata for topographic cartography, orthophotography, aerial images and documents. Its users have access to OGC CS-W and WPS implementations pertaining to content related to INSPIRE themes and local government planning. Users may search metadata and toponyms, search for municipalities and postal addresses, and add servers. Its CatalogConnector client application supports various versions of CS-W, including 2.00, 2.01 and 2.02. It sends requests to several metadata catalogs based in products as GeoNetwork GeoMedia, deegree, and con terra. The free CatalogConnector application and user guide are available for download.

United States Geological Survey: [Geospatial One Stop (GOS)]

http://gos2.geodata.gov/wps/portal/gos

Geospatial One Stop (GOS) provides domestic geospatial data for the U.S. National Spatial Data Infrastructure. Because FGDC and its partners have developed standards and models for web service data exchange, the GOS portal is somewhat unique in that its search functions can deliver data from multiple content types, hundreds of partners, pertaining to a specific theme and time period in a variety of formats including GeoRSS, KML, and HTML. Its catalog service for the web (CS-W) has been used for the GEOSS Service instance.

Community/Domain Portals

Geoportals using GWS for the sharing and analysis of geospatial data by scientific communities include the National Biological Information Infrastructure (NBII) Geospatial Interoperability Framework, FGDC Metadata , U.S. Geoscience Information Network (USGIN Lab), Marine Geoscience Data System, Oostethys, Marine Metadata Interoperability (MMI), International Coastal Atlas Network (ICAN), Group on Earth Observations GEO Portal (GEOSS) (ESA/FAO 2009), National Climate Data Center's Geodata Portal, Global Change Master Directory, Open Topography Portal, Center for International Earth Science Information Network (CEISIN), and the Global Disaster Alert and Coordination System (GDACS). Details of some follow.

GEONGrid: GEON

http://www.geongrid.org/

GEON is a worldwide collaborative that is building a cyberinfrasturcture for multi-dimensional data of the earth. The portal's front-end integrates access to public and login restricted areas. For instance, links to both custom and standard DEMs are available. Its OpenTopography Portal tab provides user access to both high resolution topographic data and tools, including CS-W, WMS, and WFS services. The OpenEarth framework also plans to provide both data and data integration models. If a user requests LiDAR point cloud data processing in the Workbench from the MyGEON tab, results of a GEON LiDAR Workflow portlet may be archived for later use.

Marine-geo: Marine Geoscience Data System

http://www.marine-geo.org

Marine-geo provides access to data portals developed by NSF, NASA, NOAA, and the USGS. Marine Geoscience Data System is distinguished by its free software GeoMapApp, which allows the user to import data, shape files and grids, and its own portals (Antarctic & Southern Ocean, Ridge 2000, MARGINS, Global Bathymetry, Seismic Reflection, National Deep Submergence Facililty and USAP Coordination Center). GeoMapApp, the user-friendly software with WFS functionality, was developed by Lamont Doherty Earth Observatory and works on any computer. The portal offers a user guide, tutorials, a virtual ocean, web services and Google Earth KMLs. Marine-geo has published excellent tutorials in terms of clarity, pace, and the information conveyed. Particularly impressive are the GeoMapApp Tutorial Movies "Web Feature Services" and "Earthquake Swarm" available through the "Multi-Media GeoMapApp Tutorials" hyperlink from the "Tutorial" hyperlink.

National Atmospheric and Oceanic Administration (NOAA): National Climatic Data Center (NCDC) Home

http://gis.ncdc.noaa.gov/geoportal/catalog/main/home.page

NCDC dynamically provides geospatial data access through the ArcGIS Server Geoportal Extension 9.3.1 and the software's WMS, WFS, KML/KMZ, and CS-W services. Service products are delivered either through map visualizations or XML. The geospatial data served includes precipitation data, climatic data, RADar (Doppler) data, and surface data. Access tools to daily, seasonal or historical data include a metadata query box and an online viewer. They provide access to station or regional data, even though response times seem a little slow.

Oostethys: Welcome to OOSTethys

http://www.oostethys.org/

Oestethys, a non-profit that develops open source tools to integrate observing systems of the oceans was formed in collaboration with SCOOP, the Southeastern Universities Research Association Coastal Ocean Observing and Prediction Program, and the Marine Metadata Initiative (MMI). It initiated the Oceans Interoperability Experiment with OGC. Oetethys is in the process of developing a test bed, with more than 1,000 platforms in a grid computing network. The grids provide resources including computing power, databases, instruments and applications. The applications, which support OGC SOS services, are written in PERL. To create interfaces for OPeNDAP, NetCDF, or RDBMS sources, JAVA and PYTHON are used. Off the "Downloads" tab, the Oostethys cookbooks in PERL, JAVA and PYTHON are available to users.

USGIN.org: US Geoscience Information Network (GIN)

http://usgin.org/

GIN is a national distributed and interoperable data network developed by state and federal geological survey online data providers. Members have developed and/or use web services (e.g., CS-W, WMS, WFS) and encodings (e.g., GeoSciML, ChemML, SensorML) to facilitate data and model access. GIN works with data providers to implement the services. A variety of software platforms use the data, including CatalgConnector, deegree, ArcGIS Explorer, ArcGIS Desktop, ArcGIS Server, GeoNetwork, GeoServer, PostgreSQL, and PostGIS. The USGIN Lab folder gives a full listing of the standards, profiles applications and implementations used is given at the USGIN Lab.

USGS: The National Map Seamless Server
http://seamless.usgs.gov/

The National Map Seamless Server permits users to explore and download national and other geospatial data from the USGS and the EROS Data Center. The data pertains to places, structures, transportation, boundaries, hydrography, orthoimagery, land cover and elevation. An OGC WMS provides data for elevation, orthoimagery and land cover. A tutorial and several application services are available. Historical data from the EROS storage system is available in pre-packaged tiles through a tiled data distribution system. Many downloads are free. By accessing the interactive map, users may request downloads of a particular area of interest by drawing a bounding box, by defining corner coordinates, or by using a provided template.

Build Your Own Solutions

Courses

OGCNetwork: Canadian Geospatial Data Infrastructure (CGDI) Online Training
http://www.ogcnetwork.net/node/612

The OGCNetwork provides tools and resources for developing and managing geospatial data. CGDI, an SDI designed to integrate geospatial data from across Canada, has several hundred partners. Its online training course, a descriptive one, has several modules enabling the user to learn the steps to publish, visualize, and access geospatial data. Standards and steps to encode, store and transfer geospatial data are described. CGDI has facilitated the enhancement of geospatial services provided by participants, and several products are offered as examples.

Penn State: Penn State GEOG 585, Geographic Markup Language
http://www.ogcnetwork.net/node/390

The OGCNetwork, as part of its educational mission, supports courses pertaining to open source tools. Penn State's course on GML provides the user an opportunity to learn, use, and be tested on GML, a required response type of WFS. Hyperlinks to several GML schemas are offered, including CityGML, GeoSciML and SensorML. GML for simple and multiple geometries, features, and application schema are introduced. Aliases for GML feature schema and an instance document are offered. The student is asked to implement a web service, to describe the usability, design, and styling of the data presented, and to document the effort.

Penn State: Penn State GEOG 585, Open Web Mapping
http://www.ogcnetwork.net/node/290

The OGCNetwork, as part of its educational mission, supports courses pertaining geospatial web mapping. Penn State's course in Open Web Mapping requires the student to understand OGC web mapping standards (WMS, WFS, GML), to describe client types, and to design and implement a web mapping solution. A paper, quizzes, and a final project must be completed. Course materials are free, although each student needs a computer satisfying minimum requirements. Penn State offers several tools helpful to users, including the GeoViz Toolkit, and ConceptVISTA.

Cookbooks/Tutorials

OGC Network provides many tools to help users develop a skill set to manage an online map service. Discussion forums, articles in the mass media, and tutorials pertaining to WMS, SOS, WCS, WFS and WPS may be found at http://www.ogcnetwork.net/learn. Some others are described in more detail here.

Community Mapbuilder: Mapbuilder Home
http://mapbuilder.sourceforge.net

> Community Mapbuilder, once supported by a collaborative, has been self sustaining via documentation, tutorials, a user-guide, and a Developers Guide. Open standards compliant (WMS, WFS(T), WCS), it provides a powerful client requiring no plugins. A stable release for download was made available in 2009. Community implementations are available through the "Examples" hyperlink. Currently SourceForge offers free services for open source software support.

Global Spatial Data Infrastructure (GSDI): Welcome to the SDI Cookbook
http://www.gsdidocs.org/GSDIWiki/index.php/Main_Page

> Doug Nebert is the information architect for the Federal Geographic Data Committee (FGDC) Secretariat and the author of the first SDI Cookbook. The cookbook has become a collaborative on-going project to keep users updated on recent standards, tools, and developments pertaining to the global SDI community. Geospatial metadata, catalogs, standards, online mapping, open access, capacity building, and case studies are described, and references and linkages provided.

MapServer: MapServer Tutorial
http://www.mapserver.org/tutorial/index.html

> The University of Minnesota provides a tutorial for MapServer, an online mapping server it initiated. The tutorial provides links to MapServer source code and *An Introduction to MapServer*. It is designed to work in both Linux and Windows environments. Beyond providing installation instructions, the tutorial provides guidance on several aspects, including CGI variables, the user interface, Mapfile, templates, expressions, raster options, processing, and mapscript.

Raskin, R. (2004). *Guide to Distributing Your Data Products Via WMS 1.1.1*: *"A Tutorial for Data Providers".*
http://oceanesip.jpl.nasa.gov/esipde/guide.html

> Rob Raskin, through NASA's Ocean Earth Science Information Partner Federation (OceanESIP), has provided a tutorial for data providers wishing to use a WMS to share their data. WMS developers select the layers, map projection, output formats, and images to be supported. They need to supply metadata in an XML file, image subsets as requested by the user. Parameters describing time-dependent data, elevation, spectral dimensions, styles, errors and specifics to a server need to be addressed as well.

Journals/Presentations

Interoperability

Ahearn, S., Almeida, D., & Gahegan, M. 2006. ***Proof of Concept and State of the Art in FOSS Geospatial Technology*** **[A Report to the United Nations Office for Coordination of Humanitarian Affairs]** http://www.reliefweb.int/rw/lib.nsf/db900sid/OCHA-6UFKXW/$file/FIGS_Working_Group_Doc_%20Final%204.pdf

Ahearn, Almeida, and Gahegan integrated several open source software products in a Field Information Geospatial-database System (FIGS) "stack" to test their efficacy for the U.N. in providing information for disaster management scenarios. Critical information needs were identified. The storage, maintenance, access, and analysis functions of the components were tested. The software evaluated included GeoTools, GeoServer, uDig, GeoWidgets, GeoAPI, MapBuilder, Jump, MapServer, GeoVista Studio, STARS, OSSIM, GRASS, the POSTGRESQL/POSTGIS environment, GAIA/Carbon Project, GDAL, Google Earth Pro, and Quantum GIS. Each tool's compatibility with ArcMap and the GEON stack was also tested. Details concerning test results are presented clearly, even for nonspecialists.

Brinkhoff, T. 2007. ***Increasing the Fitness of OGC-Compliant Web Map Services for the Web 2.0*****. Paper presented at the 10th AGILE International Conference on Geographic Information Science 2007, Aalborg, Denmark.** http://www.fh-oow.de/institute/iapg/personen/brinkhoff/paper/AGILE2007.pdf

Brinkhoff analyzes issues faced by OGC-compliant solutions in competing with non-OGC compliant providers, including Google Maps and Google Earth. By coupling mapping products with text, graphics, or hyperlinks, non-OGC compliant products are able to advertise, and to attract users who want to add their own geospatial information. Moreover the non-OGC compliant services utilize WMS services. SVG mashups are offered as an OGC compliant method of competing with such products as Google Maps because they support JavaScript and allow various coordinate systems and layers. The client handles user data. The prototype developed utilizes several tools including deegree, Postgres/PostGIS, Apache Tomcat, GeoTools and a European Petroleum Survey Group database.

Lee, C.A. & Percivall, G. 2008. ***Standards-Based Computing Capabilities for Distributed Geospatial Applications*****.** http://www.arch.ethz.ch/~sspycher/PDF/ARTICLES/08.12.09_IEEE_GeoSpatial.pdf

OGC and OGF are working together to ensure that standards for interfaces (e.g., models, encodings, and metadata) and the standards for resources (e.g., processors, storage, networks, bandwidth, data catalogs, archives, repositories, instruments, sensor networks, and computational services) support integration for distributed geospatial computing. Data access, scheduling, digital rights and workflow management, event notification, security and user authentication all are important. In OWS-6, grid computing played a function in the geo-processing workflow thread. Challenges still unresolved include simplifying tools for nonspecialist users, and handling massive data.

Geospatial Web Services, GRID Computing and e-Infrastructures

Dietz, C. 2010. Geospatial Web Services, Open Standards & Advances in Interoperability: A Selected Annotated Bibliography. *Coordinates: the Online Journal of the Map and Imagery Round Table*
http://www.stonybrook.edu/libmap/coordinates/SeriesA.htm

Dietz offers an annotated bibliography designed as a research tool to help GIS librarians and information specialists follow developments in an emerging field of geospatial web services (GWS). Issues and standards/specifications pertaining to geospatial ontologies, geospatial web services and interoperability are presented. Summaries of work and research by experts in the field are described.

Fleuren, T. & Muller, P. 2008. *BPEL Workflows Combining Standard OGC Web Services and Grid-enabled OGC Web Services*. Paper presented at the 34th Euromicro Conference on Software Engineering and Advanced Applications, Parma, Italy
http://dspace.icsy.de/handle/123456789/230

Many of the geoprocessing tasks involving large data sets require the functionality of Grid-enabled geospatial web services. Because it would be very costly to Grid-enable all web services, and because some legacy systems do not rely on geospatial web services, Fleuren and Muller propose a workflow, ActiveBPEL, to integrate XML web services, geospatial web services and Grid-enabled OGC services. The proposed workflow relies on geospatial web services, the Globus Toolkit 4 software system, service orchestration, and stateful WSRF-based Grid services. The technology discussed is complex, but addresses the management functions not addressed by GWS alone, including: security, authentication, authorization, proxy certificates, and job execution.

Lee, C. A. 2009. *e-Infrastructure Evolution, Accessibility & Societal Impacts*. A PowerPoint presented at the 4th BELIEF International Symposium in Sao Paulo, Brazil
http://portal.opengeospatial.org/files/?artifact_id=36105

Lee, President of OGF, seeks to promote distributed computing platforms, especially those involving cloud computing, Green IT, and geospatial applications. In cloud computing, nodes in the cloud provide software, platform, or infrastructure services. Lee outlines differences between cloud and Grid computing, and issues pertaining to public versus federated clouds. Select cloud initiatives are presented. OGC and OGF initiatives in OWS-6 projects (e.g. Debris flow Monitoring, Airport Disaster Response) and elsewhere are described.

Lee, C.A. & Percivall, G. 2009. The Evolution of Geospatial E-infrastructures. *GIS.SCIENCE 3*: 68-70
http://portal.opengeospatial.org/files/?artifact_id=35975

Lee and Percivall describe e-infrastructures as platforms which support applications that may use multiple data sources, and that process and consume the data possibly in multiple locations. Both OGC and OGF standards are used now to develop those geospatial applications and e-infrastructures, as in the OWS-6 airport disaster scenario. The authors suggest that both cloud computing by various governments (e.g., Japan's Kasumigaseki Cloud) and disasters such as Katrina will drive the development and interoperability of geospatial applications and infrastructures.

Padberg, A. & Greve, K. 2009. Gridification of OGC Web Services: Challenges and Potential. *GIS.SCIENCE 3*: 77-81
http://portal.opengeospatial.org/files/?artifact_id=35975

The authors, associated with the University of Bonn, offer OGC compliant users of SDIs with grid services for data and catalog access. The gaps in architecture between OGC and OGF services are bridged in the GDI-Grid Project. OGC SDI services are implemented using a Web Services Resource Framework (WSRF) in a grid middleware environment, using Globus Toolkit 4. Grid technology permits the use of redundant data storage, superior transmission capabilities, and the use of several computing nodes per process execution. Spatial tiling mechanisms permit parallelized processing. Bridging the two architectures requires several semi-automatic steps including the automatic creation of a WSDL document, and others using middleware, such as OGSA-DAI. The impact for the use of such a bridge in the geospatial domain is not clear. Another discussion of the likely impact is presented by Padberg and Kiehle (Padberg and Kiehle 2009).

Reed, C. 2008. GRID Computing and the Geospatial Web: The Role of Standards. A PowerPoint presented at the Mardi Gras Conference in Baton Rouge, LA http://www.ogcnetwork.net/ogcpresentations

Reed, the Chief Technical Officer of OGC, suggests that an enormous effort is required to integrate and access the most current and appropriate geospatial data residing in tens of thousands data repositories. He cites several implementations of Grid technology integration with OGC services, with the CS-W service providing transparent access to data and services. Several areas needing development by OGC include access control, registry formalism, and integrating grid security and workflow concepts. Highlights of SEE-GEO and SAW-GEO initiatives are given.

Woolf, A. & Shaon, A. 2009. An approach to encapsulation of Grid processing within an OGC Web Processing Service. *GIS.SCIENCE 3*: 82-88
http://portal.opengeospatial.org/files/?artifact_id=35975

Woolf and Shaon focus using Grid processing to add value to a WPS so that the geoprocessing and analytical capability for models and large datasets may be enhanced and secure. Grid computing provides a framework needed by GWS to construct complex workflows using several computing nodes if needed. Job Submission Description Language (JSDL), an OGF specification, describes the data and computational resources needed for an implementation. When combined with the WPS process description and data, a valid JSDL can be formed to manage a large computational process. The authors outline the steps to create a Grid-enabled WPS service and note an implementation in OWS-6 (Scene 4 in the Geoprocessing demonstration).

References

Almirall, P.G., Bergada, M.M. & Ros, P.Q. 2008. The Socio-Economic Impact of the Spatial Data Infrastructure of Catalonia. [Internet]. [Cited February 28, 2010]. Available from: http://www.geoportal-idec.net/geoportal/eng/docs/impact_study_report.MAX.pdf

Baumann, P. & Aiordachioaie, A. 2009. Preserving GeoScientific Data Assets through Service Interoperability. [Internet]. [Cited February 28, 2010]. Available from:

http://www.sciops.esa.int/SYS/CONFERENCE/include/pv2009/papers/23_Baumann_GeoDataServiceInterop.pdf

Baumann, P. & Aiordachioaie, A. 2009. Preserving GeoScientific Data Assets Through Service Interoperability. [Internet]. [Cited February 28, 2010]. Available from: http://www.sciops.esa.int/SYS/CONFERENCE/include/pv2009/talks/20091202-1230-AndreiAiordachioaie.ppt

Botts, M. 2008. Open Geospatial consortium Sensor Web Enablement. [Internet]. [Cited February 28, 2010]. Available from: http://vast.uah.edu/downloads/presentations/SWE_GWG_2008-10-16.ppt#256

Broering, A., Juerrens, E.H., Jirka, S. & Stasch, C. 2009. Development of Sensor Web Applications with Open Source Software. [Internet]. [Cited February 28, 2010]. Available from: http://ifgi.uni-muenster.de/~arneb/OSGIS_209_FullPaper_broering_jirka_juerrens_stasch.pdf

Fischer, F. 2009. A review of arcGIS Desktop 9.3: Do we Still need a Desktop GIS?. [Intenet]. [cited February 28, 2010]. Available from: http://www.esri.com/library/reprints/pdfs/geoinformatics_desktopgis.pdf

GeoConnections: About GeoConnections. [Internet]. [cited February 28, 2010]. Available from: http://www.geoconnections.org/en/aboutGeo.html

Hobona, G., Fairbairn D., Hiden, H. & James, P. In Press. Orchestration of Grid-enabled Geospatial Web Services in Geoscientific Workflows. [Internet]. [Cited February 11, 2010]. Available from: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4838226&isnumber=4358066

Janowicz, K., et al. 2009. [Internet]. [Cited March 1, 2010]. Available from: http://sunsite.informatik.rwth-aachen.de/Publications/CEUR-WS/Vol-518/terra09_submission_7.pdf

Lieberman, J. 2008. OGC Catalog Services CS/W, ebRIM, Service Profiles, Metadata & Metametadata. [Internet]. [Cited February 28, 2010]. Available from: http://www.ogf.org/OGF22/materials/1075/CSW_LiebermanFidelman.ppt

Longhorn, Roger. 2009. Evaluating SDI Best Practice. [Internet]. [cited February 23, 2010]. Available from: http://www.gsdi.org/gsdiconf/gsdi11/wrkshpslides/w2.2a.pdf

Nebert, Doug, Reed, Carl, and Wagner, Roland M. 2007. Proposal for a Spatial Data Infrastructure Standards Suite: SDI 1.0 [Internet]. [cited February 23, 2010]. Available from: http://www.gsdidocs.org/gsdiconf/GSDI-9/papers/TS19.1paper.pdf

Padberg, A. & Kiehle, C. 2009. *Towards a Grid-Enabled SDI: Matching the Paradigms of OGC Web Services & Grid Computing*. [Internet]. [cited February 11, 2010]. Available from: http://www.gsdi.org/gsdi11/slides/tues/1.4d.pdf

Reed, C. 2006. *An Introduction to GeoRSS: A Standards Based Approach for Geo-enabling RSS feeds*. [Internet]. [Cited February 11, 2010]. Available from: http://www.opengeospatial.org/pt/06-050r3

Robin, A., Giacobbo, D., & Smolders, S. 2007. *Online Data Access Using WCS and GMLJP2*. [Internet]. [Cited February 11, 2010]. Available from: http://earth.esa.int/rtd/Events/SSE_2007/SSEW07_20_SPOTIMAGE_WCSGMLJP2forSSE.ppt

Sonea, P. 2008. *GeoMedia and GeoMedia WebMap Update*. [Internet]. [cited February 28, 2010]. Available from: http://www.intergraph.com/global/ca/assets/local/GeospatialProductUpdate_PeterSonea.pdf

Steenmans, C. 2009. The Future of Environmental Information Sharing. [Internet]. [Cited February 23, 2010]. Available from: http://www.gsdi.org/gsdiconf/gsdi11/slides/tues/Steenmans.pdf

Turton, I. & Murdoch, A. 2008. *A Web Based tool for the Detection and Analysis of Avian Influenza Outbreaks from Internet News Sources.* [Internet]. [Cited February 11, 2010]. Available from: http://mapcontext.com/autocarto/web/documents/AutoCarto2008/Turton.pdf

Wang, F., et al. 2009. Eight Times Acceleration of Geospatial Data Archiving and Distribution on the Grids. [Internet]. [Cited February 11, 2010] Available from: doi:10.1109/TGRS.2008.2010055