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Evaluation of OGC Standards for Use in LLNL GIS

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Over the summer of 2005, the Lawrence Livermore National Laboratory (LLNL) Computer Applications and Research Department conducted a small project that examined whether Open Geospatial Consortium (OGC) standards might be useful in meeting program mission requirements more effectively. OGC standards are intended to facilitate interoperability between geospatial processing systems to lower development costs and to avoid duplication of effort and vendor lock-in. Some OGC standards appear to be gaining traction in the geospatial data community, the Federal government, Department of Energy (DOE) and Department of Homeland Security (DHS) and so an evaluation was deemed appropriate.

INTRODUCTION

Geographic data are used by many programs at LLNL. Groups focused on Geographic Information Systems (GIS) exist in both the Energy & Environment Directorate and in the Engineering Directorate, with the Engineering team focusing on spatial analysis and the Energy & Environment providing general GIS capabilities. Many specific programs need geospatial information to meet their mission requirements. So effective means of acquiring, processing and presenting these data are of interest to the Laboratory and geospatial interoperability can potentially provide these means.

Background

While geographic data are used in a variety of applications, traditional implementations of geospatial processing capabilities have been associated with large expenses, including:

- production or identification of datasets
- transforming external data into forms that can be used locally
- acquiring and maintaining knowledge of complex GIS user interfaces
- development of application programs using packages with complex interfaces
- development of custom software to meet specific needs

The use of geospatial data has been limited by the expense of acquiring and maintaining the data and technology necessary to integrate geospatial processing into systems.

The issue of inefficiency in managing geographic data was identified as early as 1982 (Federal Geographic Data Committee 2004). For example, data sets are often redundant, having been previously produced by multiple organizations. Such redundancies can be attributed to the lack of knowledge of available data sets and the difficulty and expense transforming external data sets in myriad formats into usable forms for a particular system or application. There are many organizations that are playing a role in attempting to improve the efficiency of geospatial data management. The Federal Geographic Data Committee (FGDC) has promoted "the coordinated use, sharing and dissemination of geospatial data" since 1990 upon the issuance of Office of Management and Budget (OMB) Circular A-16, which mandates more effective use of geospatial use in the Federal government (Federal Geographic Data Committee 2006).

The efforts of the FGDC are focused on the creation of a National Spatial Data Infrastructure (NSDI), which has four components:

1. *Metadata* – a standard for the description of data that allows potential consumers to evaluate the data.
2. *Clearinghouse* – a public collection of metadata that supports the discovery of potentially useful datasets.
3. *Standards* – technical specifications that allow systems to exchange geospatial information (Federal Geographic Data Committee 2006).
4. *Framework* – numerous commonly used datasets that are maintained by Federal agencies for public use, e.g., elevation and transportation, that provide a consistent base of information for mapping and analysis.

The NSDI has been evolving since the early 1990s and is becoming a practical reality in the form of the Geospatial-One-Stop (Geospatial One-Stop 2006).

While the NSDI fulfills some necessary conditions for effective geospatial data use, by themselves these components have not been sufficient to reach the goal of geospatial interoperability. Geospatial interoperability means that heterogeneous, independently-managed, distributed systems can interact effectively on the basis of requests for services and data based on mutually understood formats and conventions. The Open Geospatial Consortium (OGC) is a consortium of commercial, government and university organizations with the goal of promoting geospatial interoperability (Open Geospatial Consortium 2006), i.e., the OGC is working towards filling the gap between NSDI capabilities and geospatial interoperability. While OGC has many efforts that support this goal, this paper focuses on standards development. OGC standards include conceptual

models, data formats and interfaces that facilitate communication, interpretation and integration of data and services. Thus, OGC moves beyond FGDC and other involved standards organizations such as ISO by standardizing interfaces for communication between systems that exchange geospatial data and processing and defining detailed implementation specifications that allow software developers to build applications in differing technologies that interoperate.

Scope

In approaching the issue of geospatial data standards and geospatial interoperability, the enormous number of relevant standards must be considered. The FGDC and OGC, as well as other organizations, have dozens of standards in various states of development. These standards are typically built on numerous other standards such as XML that are not specifically associated with geospatial data. OGC standards have been selected for this discussion because they are detailed enough to allow developers to build working implementations and are therefore likely candidates for integration into LLNL projects.

APPROACH

Selection of standards

The full range of OGC standards is too large to consider in a project of limited scope (Open Geospatial Consortium 2006). Fortunately, the industry focus on OGC standards at this time involves a smaller subset. The two OGC standards gaining the most traction in the commercial and government sectors are the Web Mapping Service (WMS) and the Web Feature Service (WFS). Thus, these two standards form the core of the focus here. However, these standards are not complete in and of themselves. They are built

upon a number of other OGC and non-OGC standards. Building real WMS or WFS applications implies the use of the Stylized Layer Descriptor (SLD), Web Map Context Documents (WMC), Catalog Services Specification (CAT), Coordinate Transformation Services (CT), Simple Feature Specification (SFS), and Geographic Markup Language (GML) OGC standards. Consequently, these standards are considered here. Also, because of the interest in sensors by a number of LLNL programs, the OGC Sensor Model Language (SML) and Observations and Measurements (O&M) standards have been included. All of these standards are built on non-OGC standards such as XML and GeoTIFF, but these standards will be mentioned only in passing.

Figure 1 provides a representation of how these standards are related. A WMS allows a client to request a map of a region and returns an image in one of several commonly used formats displayed by any browser (e.g., JPEG). In contrast, a WFS returns the actual data, which allows the client to perform processing and analysis on that data. WMS are supported by two other standards, the WMC, which allows the products of multiple WMS to be integrated into a single product or display and the SLD, which allows clients to control details of how an image is displayed (e.g., the color of map labels). A WFS returns the geographic features in GML, which is an XML-based standard for describing any geographic feature. GML is built on the CT and SFS standards and is central to many OGC specifications. In particular, the O&M standard uses GML to represent observations. Additional information about these standards and their relationships is provided in the Results section.

Evaluation of standards

Each standard was read by one or more participants in the project, with a few of the most central standards being reviewed by most or all of the participants. Participants were established developers supporting a cross section of sponsors and domain applications at LLNL. The standards were discussed to clarify the relationships between the standards and the difficulty of implementation or integration into current or future projects. In addition, the integration of OGC capabilities into the Environmental Systems Research Institute (ESRI) GIS was evaluated as an indicator of commercial acceptance. The applicability of these standards to LLNL programs was evaluated.

RESULTS

Summary of standards

WMS (Web Map Service) allows clients to receive descriptions of layers, coordinate reference systems (CRS), output formats and display styles supported by the service. Clients can request available layers in supported CRS, display styles and output formats. WMS implementations usually provide image data (e.g., JPEG) to be displayed at the client's system.

WFS (Web Feature Service) allows clients to receive descriptions of layers, feature types, and CRS supported by the service. Clients can request available features in supported CRS. The output of a request is normally in GML.

GML (Geography Markup Language) supports a rich means of describing geographic features. It covers both 2- and 3-dimensional features. It supports the description of CRS, observations, units and temporal coordinate systems.

CAT2 (Catalogue Service) supports service registration, description and discovery.

CT (Coordinate Transformation Service) allows locations, CRS and transformations to be described, implemented and combined.

SFS (Simple Features Specification) provides interfaces and structures that allow geographic features to be expressed in SQL, COM and CORBA.

SLD (Stylized Layer Descriptor) controls of the symbolization features in a layer.

WMC (Web Map Context) manages of collections of multiple maps.

SML (Sensor Modeling Language) provides sensor information in support of data discovery, the processing and analysis of the sensor measurements, the geolocation of observed values, and archival of fundamental properties and assumptions about a sensor. SensorML is a part of the OGC's Sensor Web Enablement (SWE) activity, which establishes interfaces and protocols to enable applications to access sensors of all types.

O&M (Observations and Measurements) captures data about some phenomenon, binds observation, spatial, and temporal data together and provides a common data format to record any type of data. O&M is a part of the SWE activity.

Commercial Support for OGC Standards

One way to evaluate the acceptance and practical value of geospatial standards is to examine the support they receive from commercial GIS vendors. While a full evaluation of the commercial sector would be a significant project in itself, a far narrower, but useful, perspective can be gained by evaluating the support ESRI is providing. While a single vendor certainly limits the scope of any conclusions, the fact that ESRI provides 80-90% of the Federal government GIS implementations indicates that such conclusions are of practical value.

ESRI currently supports a subset of OGC standards via desktop extensions, and server connectors and extensions (Environmental Systems Research Institute 2006). ESRI currently supports GML 2.1.2 in ArcGIS 9.1 via extensions and will support GML 3 in

ArcGIS 9.2. ESRI is also taking a lead role in evolving the GML standard. In particular, they are pushing the development of a simpler GML standard (SF-GML) for 2-dimensional geospatial data. ESRI is improving existing support of WMS and WFS and adding new standards in their ArcGIS 9.2 release. ESRI currently supports WFS 1.0, but considers the 1.1 standard to be in flux and is delaying server-side support. For more details, visit http://www.esri.com/software/standards/ogc-support.html. ESRI is showing a significant commitment to the support of the key OGC standards considered in this paper.

While the ESRI is providing significant OGC support, it is important to note that much of this support comes by way of the ArcGIS Data Interoperability Extension available for desktop, server, and development products. The availability of these extensions demonstrates a willingness by GIS vendors to support interoperability standards. The lack of built-in support (without use of extensions) for many of the OGC standards (GML, Coverages, etc) may indicate limited user interest or slow adoption of the standards. Built-in support for web-based standards such as WFS and WMS is provided by most GIS vendors, including non-ESRI products.

Evaluation of OGC Standards for the GEn&SIS Project

The Nuclear Regulatory Commission (NRC) Geographical, Environmental, & Siting Information System (GEn&SIS) project is a web-based GIS that supports data reconnaissance for nuclear reactor site licensing and license renewal using public data. The graphics and supporting data are used to support decisions in the Environmental Impact Statements and justify those decisions in public hearings. The main goal of the project is to take the raw data and present it in a final form, with all intermediate steps

being transparent to the user. These intermediate steps include substantial post-processing and statistical calculations. Although the client base includes a number of users very familiar with GIS, their interest is in the generated maps and supporting data. The system was originally to be made available to the public, however, aggregate data sensitivity issues led to restricting the user base.

The original implementation used X-Windows with a web interface for specifying input parameters. It became increasingly cumbersome and expensive to maintain a custom GIS and the project moved to an ESRI ArcIMS implementation. The selection ArcIMS was driven by common use of ESRI products at LLNL and in government.

Given the project's status, the implementation of a data distribution format such as GML would not provide a clear benefit for the current customer base. However, if these data were to be made valuable to the public, an effective way to make the data (not an image of the data) available would be using GML. Lacking support for complex spatial queries against feature sets, the WFS could not directly replace the current system. A WMS could contribute to this application by supporting data display; however, the WMS would not allow access to the underlying, processed data or the metadata. GML could be used for metadata and processed data distribution, but this would require a substantial reengineering of the current system that is inconsistent with the current goals and funding. In summary, there are advantages to avoiding the vendor lock-in associated with using ESRI proprietary protocols and data formats. However, until ESRI more fully integrates OGC support into ArcIMS, there does not appear to be a cost-effective way to migrate this project to an OGC standards-based implementation.

Evaluation of OGC Standards for the NARAC Program

The National Atmospheric Release Advisory Center (NARAC) provides tools and services that map the spread of hazardous material released into the atmosphere. NARAC is a national support and resource center for planning, preparedness, real-time emergency response, and detailed assessments of threats or incidents involving a wide variety of hazards, including nuclear, radiological, chemical, biological or natural emissions. NARAC products provide information on affected areas, potential casualties, health effects, and recommended protective actions. NARAC is a distributed system providing modeling tools for deployment to an end user's computer system as well as real-time access to quality-assured, advanced model predictions from the national center There are numerous ways in which NARAC could utilize of OGC standards:

1. *Product generation* – NARAC currently interoperates with GIS by creating ESRI shape file representations of the hazard zones associated with an atmospheric release. GIS interoperability could be improved with a GML representation of NARAC products. A NARAC GML product would only require limited portions of GML and so could be implemented cost-effectively.
2. *WMS/WFS client* – Extending NARAC mapping and visualization capabilities to allow the selection and import of map layers from existing, external WMS could be added to the system without difficulty (similar integration of non-OGC image map services has already been completed). A WFS capability would require GML support that would require some additional effort.
3. *NARAC WMS/WFS service* – Processing the WMS protocol does not raise difficulties and NARAC already produces dispersion pattern images in supported formats and so

a core WMS capability would not be difficult to implement. However, creating a product discovery mechanism from the applicable standards would require a significant design effort, as would the integration of a security model. A WFS implementation would also involve the creation of GML products.

In summary, delivering GML products and developing a WMS client capability seem to be valuable and inexpensive enough to be given near-term consideration. Other applications of OGC services involve larger efforts and will wait for sponsor requests.

Evaluation of OGC SensorML and O&M for LLNL Programs

Many lab projects could benefit from the use of SensorML and O&M for data interoperability but few projects have an immediate need to implement them. In the long term, all projects producing or archiving sensor data should be aware of these models to facilitate data interoperability and long-term data archival. Areas that could potentially benefit from SensorML and O&M include NARAC (meteorological and sampler data), radiation detection (long-term or baseline measurements and configuration data), geology (seismic data for natural and artificial events), biology (time-based air samples and automated test results) and ARGUS (motion detection, "alarm" conditions). Future projects should consider implementing SensorML for sharing and storing sensor metadata. SensorML would increase interoperability between projects by providing a standardized method of expressing sensor differences so that supporting software could transform data to consistent representation. Future projects should also consider using as O&M as a data format for storing and transferring data. O&M could be used to replace existing data formats to facilitate long-term storage of the data. Other projects may benefit from using O&M for data interoperability to minimize problems of cross-platform

use and to clarify the meaning of the data. However, O&M is currently a proposal and is unsupported commercially. O&M and SWE are standards that bear watching but are not mature enough to drive current efforts at LLNL.

SUMMARY

OGC standards are having growing impact on the GIS community and it is important to be aware of their development. On the other hand, many of the standards and standard groupings are immature and evolving rapidly. Consequently, LLNL developers should generally take a measured approach by identifying specific applications where focused use of specific OGC standards can provide cost-effective solutions. General application of OGC standards should wait for the standards and the implementations of these standards to mature. It is important to note that OGC standards reflect common denominator capabilities and so performance may suffer relative to proprietary solutions. A broader question is to what degree, if any, should LLNL participate in the standards development process and attempt to drive the standards in directions that would be useful to the Laboratory. In most cases, the application of geospatial technology at Livermore is too focused on specific program needs to justify the commitment necessary to have an impact on the OGC standards development process. A possible exception might be in the Sensor Web Enablement effort, where important Homeland Security related work at LLNL is closely tied to integrating sensor data with other information systems and might benefit from standards that reflected LLNL requirements.

The overriding issues of geospatial data sharing and interoperability are being addressed on several fronts and important progress is being made. However, the promise

of a true National Spatial Data Infrastructure is short of fruition. Continued evolution of OGC standards and implementations coupled with growing participation from the geospatial data user community is required. As enabling technologies that support this infrastructure mature, it is also important that institutional and political barriers to data sharing be resolved so that the effective use can be made of these emerging capabilities.

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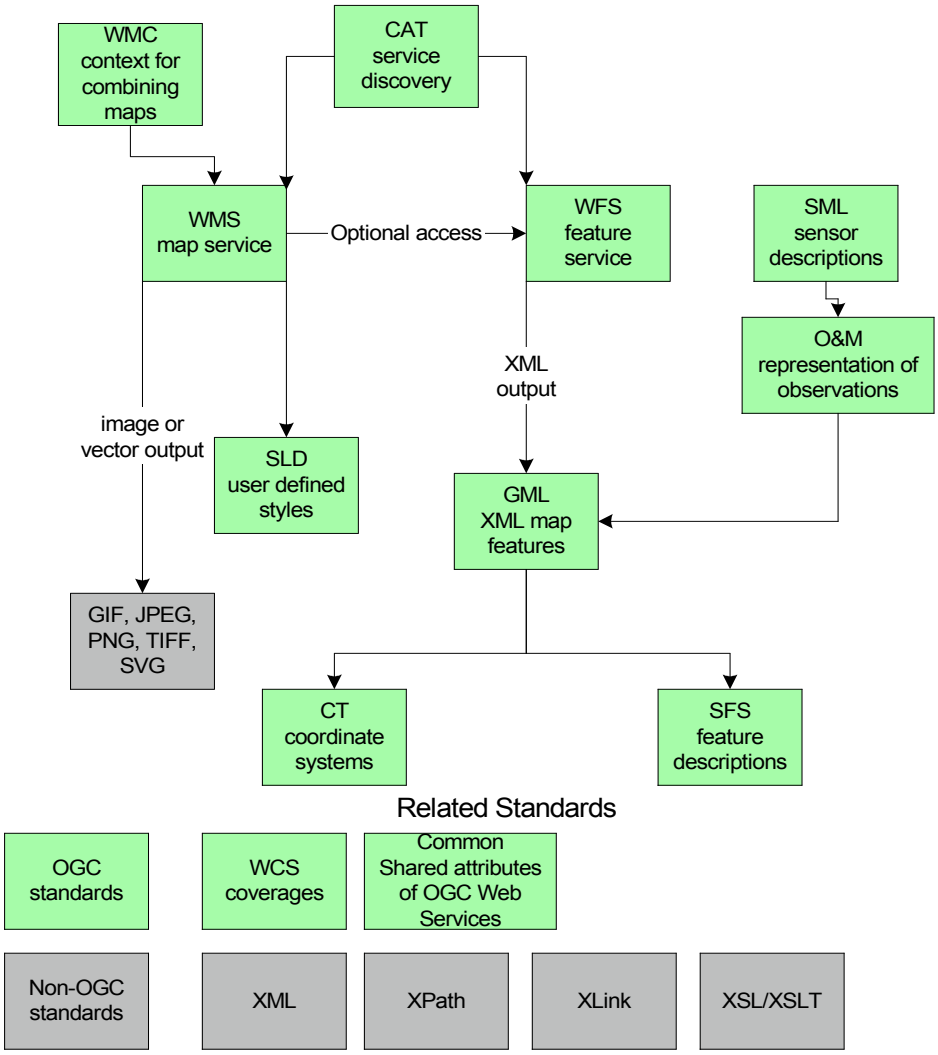

Figure 1. Relationships between key OGC standards.

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