Spatial Data Standards and GIS Interoperability

An ESRI® White Paper • January 2003

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Overview

Geographic information system (GIS) technology is evolving beyond the traditional GIS community and becoming an integral part of the information infrastructure in many organizations. The unique integration capabilities of a GIS allow disparate data sets to be brought together to create a complete picture of a situation. GIS technology illustrates relationships, connections, and patterns that are not necessarily obvious in any one data set, enabling organizations to make better decisions based on all relevant factors. Organizations are able to share, coordinate, and communicate key concepts between departments within an organization or between separate organizations using GIS as the central spatial data infrastructure. GIS technology is also being used to share crucial information across organizational boundaries via the Internet and the emergence of Web Services.

To fully realize the capability and benefits of geographic information and GIS technology, spatial data needs to be shared and systems need to be interoperable. GIS technology provides the framework for a shared spatial data infrastructure and a distributed architecture. ESRI has developed its products based on open standards to ensure a high level of interoperability across platforms, databases, development languages, and applications. ESRI is also committed to supporting and actively leading efforts associated with interoperability and the development of standards.

This white paper discusses the value of being "open," the evolution of spatial standards with the development of new technologies, including the future of Web Services, and provides an overview of where ESRI is concentrating its efforts with regards to interoperability.

What Does Being an "Open" GIS Mean?

To put this question into context, it is important to understand that during the past 20 years, the concepts, standards, and technology for implementing GIS interoperability have evolved through six stages.

1. Data converters (DLG, MOSS, GIRAS)

2. Standard interchange formats (SDTS, DXF™, GML)

3. Open file formats (VPF, shapefiles)

4. Direct read application programming interfaces (APIs) (ArcSDE® API, CAD Reader, ArcSDE CAD Client)

5. Common features in a database management system (DBMS) (OGC Simple Feature Specification for SQL™)

6. Integration of standardized GIS Web services (WMS, WFS, ArcIMS)

All six of these approaches and related technologies are important and continue to play a significant role in GIS interoperability today. In early years, the constraints of computational speed and cost limited our ability and caused us to focus on practical solutions such as direct file conversion. Data sharing between organizations with different GIS vendor systems was limited to data converters, transfer standards, and later open file formats. Sharing spatial data with other core business applications was rarely achieved. Today, most GIS products directly read and sometimes dynamically transform data with minimal time delay. The point here is that the GIS community has been pursuing open interoperability for many years, and the solutions to achieving this goal have changed with the development of new technologies.

Another factor to be considered is the still evolving view of the role that GIS plays in an organization. In the early days of GIS, the focus, with rare exceptions, was on individual, isolated projects. Today the focus is on the integration of spatial data and analysis in the mission-critical business processes and work flows of the enterprise and on increasing the return on investment (ROI) in GIS technology and databases by improving interoperability, decision making, and service delivery.

Finally, it is worthwhile to remember why we implement geographic information system technology in the first place. Even if we have specialized responsibility for gathering and managing geographic data, we need to remember that a GIS is not an end in itself. A GIS must produce useful information products that can be shared among multiple users, while at the same time provide a consistent infrastructure to ensure data integrity. It is important not to get caught up in the technology and forget this basic principle. Interoperability enables the integration of data between organizations and across applications and industries, resulting in the generation and sharing of more useful information.

The Value of Being Open

An open GIS system allows for the sharing of geographic data, integration among different GIS technologies, and integration with other non-GIS applications. It is capable of operating on different platforms and databases and can scale to support a wide range of implementation scenarios from the individual consultant or mobile worker using GIS on a workstation or laptop to enterprise implementations that support hundreds of users working across multiple regions and departments. An open GIS also exposes objects that allow for the customization and extension of functional capabilities using industry-standard development tools.

A state chief information officer, for example, would expect an enterprise GIS solution to provide a spatial data warehouse supporting shared spatial data and services across multiple agencies such as transportation, environmental protection, natural resources, state police, and information technology (IT). Each agency might also have a local database to update and maintain the framework data for which the agency is responsible and provide an e-government portal for public access. Today's "always on" availability requirements and the growing security considerations also dictate that any GIS solution operate in clustered, high-availability environments and be easily replicated to remote backup server locations.

ESRI has a large team of people involved in each of the phases of developing open standards including creating standards, reviewing standards, and integrating standards into our products. ESRI also works with a number of standards organizations and directly participates in the creation, review, and introduction of industry standards. ESRI's efforts are focused on two major areas:

- GIS data and technology interoperability
- Interoperability of GIS technology with other technologies and systems

GIS Data and Technology Interoperability

Many organizations need a GIS capable of integrating services and data from multiple sources and in different formats. ESRI's technology and products support this level of interoperability, and its active role in the development of open standards has helped ensure that ESRI® data can be easily accessed by other technologies and applications. ESRI products support numerous data converters and direct read access including Spatial Data Transfer Standard (SDTS), Vector Product Format (VPF), imagery, computer-aided design (CAD) files, digital line graph (DLG), and TIGER®. Of equal importance, ESRI systems enable organizations to share GIS services and communicate across different vendor implementations. An open, distributed, and networked GIS architecture provides the framework for sharing data and services.

Metadata Support

ESRI recognizes that in order to build a strong spatial data infrastructure, metadata is crucial. As a result, in addition to supporting standard data formats, ESRI also supports standard metadata representations. Metadata and metadata servers enable users to integrate data from multiple sources, organizations, and formats. Metadata for geographical data may include the data source, its creation date, format, projection, scale, resolution, and accuracy.

The ArcGIS™ Desktop products (ArcView®, ArcEditor™, and ArcInfo™) allow users to create, manage, and edit metadata stored in an XML representation of Federal Geographic Data Committee (FGDC) Content Standards for Digital Geospatial Metadata or of the ISO 19115 Metadata Standard.

ArcIMS® Metadata Services enable users to create a central, online metadata repository that facilitates publishing and browsing metadata over the Internet. The metadata documents stored as ArcIMS Metadata Services can then be accessed using any client that communicates using ArcXML such as

- **ArcCatalog:** ArcCatalog™ is the geographic and tabular data management, creation, and organization application for ArcGIS Desktop.

- **ArcIMS Metadata Explorer:** A set of JavaServer™ Pages (JSP) that can be used to build a customized, browser-based means of searching for metadata.

- **Z39.50 Clients:** Z39.50 is a national standard that defines a protocol for computer-to-computer information retrieval.

- **ISO 239.50 Clients:** ISO 239.50 is an international standard that defines a protocol for computer-to-computer information retrieval.

Interoperability of GIS Technology With Other Technologies and Systems

ESRI has also given great attention to the relationship between GIS and the rest of the IT infrastructure. For our users, this means compatibility and interoperability with major enterprise systems such as enterprise resource planning (ERP), customer resource management (CRM), enterprise application integration (EAI), work management systems, decision support systems, and others.

Platform-Independent Solutions

GIS software is increasingly used in large multiuser environments where spatial data is accessed using a variety of platforms and devices from relational database management systems (RDBMS) residing on a wide assortment of servers and operating systems. In order to be open, therefore, a GIS must support platform-independent solutions implemented in heterogeneous environments composed of different server hardware; operating systems; networks; databases; development tools; and desktop, Web, and mobile clients.

ESRI's recognition of the importance of an open, platform-independent product strategy is reflected in its products.

- Strong support for high-end ArcGIS Desktop clients (ArcView, ArcEditor, and ArcInfo) on modern Windows® (2000, NT, XP) operating systems

- Support for pervasive computing devices on numerous platforms including Web browsers (via HTML), Java™ clients (MapObjects®—Java, ArcExplorer™, and ArcSDE—Java API), Tablet PC, Windows CE- and Pocket PC-based devices (ArcPad®), ultra thin clients (Web services: ArcWeb℠ USA), and standards-based wireless devices such as wireless application protocol (WAP) phones, the Smartphone, and so forth.

- Advanced application servers and Internet-based GIS Web servers on Linux®, UNIX® (HP®, IBM® AIX®, and Solaris™), and Windows.

- Support of the leading commercial database vendors (IBM DB2®, IBM/Informix® Dynamic Server™, Microsoft® SQL Server, and Oracle®)

- Support for TCP/IP-based LAN, WAN, and wireless networks

- Extensive support for standard developer environments (VB, C++, .NET, Java—J2ME, J2SE, J2EE, ASP/JSP, etc.)

The Evolution of Spatial Standards

To fully understand how ESRI envisions spatial standards and GIS interoperability evolving, it is important to review how spatial standards have evolved over the years. Until the mid-'90s, organizations purchased geographic information systems that closely tied applications to a native, proprietary spatial data model. These early nonrelational file structures were highly optimized for fast access to data and, being file based, were relatively easy to distribute between sites using the same GIS vendor software. However, the ability to share data among users within an organization was limited by network protocols such as network file system (NFS). Data sharing between organizations with different GIS vendor systems was limited to data converters, transfer standards, and later open file formats. Sharing spatial data with other core business applications was rarely achieved.

The Georelational Database

Gradually, GIS models evolved into georelational structures where related attribute data could be stored in a relational database that was linked to the file-based spatial features. However, the georelational format had limited scalability, and the dual data structure (spatial features stored in proprietary file-based format with attributes stored in a relational database) meant that the GIS could not take full advantage of relational database features such as backup and recovery, replication, and fail-over. In addition, supporting large data layers required the use of complex tiling structures to maintain performance, and sharing spatial information with other core business applications was still not possible.

The Spatially Enabled Database

In the mid-'90s, new technology emerged that enabled spatial data to be stored in relational databases (often referred to as spatially enabling the database), opening a new era of broad scalability and the support of large, nontiled, continuous data layers. When the new spatially enabled databases were combined with client development environments that could be embedded within core business applications, the sharing of spatial features with core business applications, such as customer management systems, became possible. In addition, these spatially enabled databases allowed organizations to take the first steps toward enterprise GIS and the elimination of organizational "spatial data islands."

Perhaps not coincidently, the open GIS movement was spawned shortly after the arrival of the first all-relational models capable of storing both spatial and attribute data in a relational database when standards organizations, such as the Open GIS Consortium (OGC), the International Organization for Standardization, and the U.S. Federal Geographic Data Committee, began promoting the idea of data sharing through spatial data standards. The early work of these organizations was focused on sharing simple spatial features in a relational database, thereby enabling interoperability between the commercial GIS vendors. OGC, an international industry consortium of private companies, government agencies, and universities, published an open spatial standard called the Simple Features Specification.

ESRI actively participated in the definition of the OpenGIS Simple Features Specification and was the first vendor with products to successfully complete OGC's conformance testing. In fact, ESRI is the only vendor with both client and server products that conform to the OpenGIS Simple Features Specification for SQL. It is worth noting that ArcSDE, ESRI's solution for managing vector data in an RDBMS, uses the default binary schema for Oracle and SQL Server, which is fully compliant with the OpenGIS Simple Feature Specification for SQL's binary geometry. ArcSDE also provides support for additional GIS data types such as *z* values, measures, annotation, and support for raster and survey data that extend beyond the OGC specification.

The Future With Web Services

As GIS technology continues to evolve, the question that many organizations are asking today is, "What is the best long-range solution for data sharing and interoperability?" ESRI believes the answer is Web services, an area ESRI is focusing much of its research and development efforts on today.

Web services avoid the issues and complications of GIS applications being tied to the spatial schema of a specific RDBMS vendor and allow GIS vendors to manage their own data using the best methods and formats for their tools in whatever database environment they choose. In addition, Web services allow server-to-server sharing of data and services, as opposed to integration only happening at the client level as it does with standards that are focused on the DBMS. Some vendors, such as ESRI, choose to use an RDBMS with schema and methods that perform optimally for their tools. Others use file systems. Web services mean that each GIS vendor can build and manage its own GIS data and readily provide GIS services (data, maps, and geoprocessing) to a larger audience in a common environment.

Web Services Framework

Web services are a fundamentally new framework and set of standards for computing. Web services envision a network of distributed computing nodes, which can include servers, workstations, desktop clients, and lightweight "pervasive" clients (phones, PDAs, etc.). Web services standards provide the glue by which these computers and devices interact to form a greater computing whole, accessed from any other device on the network. It is also important to recognize that Web services are not just for the Internet; they represent a powerful architecture for all types of distributed computing.

Web services provide a framework for fusing computing devices via open networks (the Internet, wireless, and local networks). In Web services, computing nodes have three roles: client, service, and broker. A client is any computer that accesses functions from one or more other computing nodes on the network. Typical clients include desktop computers, Web browsers, Java applets, and mobile devices. A client process makes a request of a computing service and receives results for each request. A service is a computing process that awaits requests, responds to each request, and returns a set of results. A broker is essentially a service metadata portal for registering and discovering services. Any network client can search the portal for an appropriate service. Server and broker technologies are typically used on UNIX, Linux, and Windows platforms.

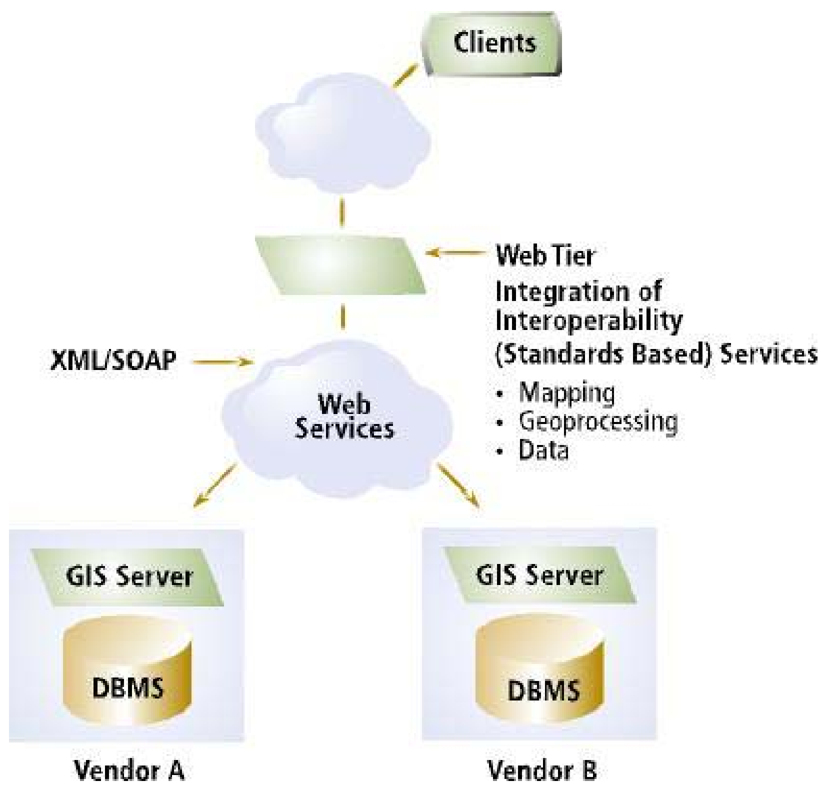
Web services can support the integration of information and services that are maintained on a distributed network. This is appealing in organizations, such as local governments, that have entities or departments that independently collect and manage spatial data (e.g., roads, pipes, surveys, land records, administrative boundaries). At the same time, many of the functions of a local government require these data sets to be integrated. The use of Web services (a connecting technology) coupled with GIS (an integrating technology) can efficiently support this need. The result is that the various layers of information can be dynamically queried and integrated, while at the same time the custodians of the data can maintain this information in a distributed computing environment.

The Standards for Web Services

The key standards used for Web services are a series of protocols (i.e., XML; Simple Object Access Protocol [SOAP]; Web Services Description Language [WSDL]; and Universal Description, Discovery, and Integration [UDDI]) that support sophisticated communications between various nodes in a network. They enable smarter communication and collaborative processing among nodes built within any Web services-compliant architecture.

Web services can be accessed with devices such as browsers, mobile devices such as telephones, desktop clients, and other information appliances. To discover these services, a broker is provided. The discovery protocol is referred to as a Universal Description, Discovery, and Integration. In the GIS context, the UDDI node plays the role of a metadata server of registered Web services. A user can search a UDDI directory and find other distributed service providers or services that exist on a network.

Web services interoperate (communicate) through an XML-based protocol known as Simple Object Access Protocol. This is an XML API to the functions provided by a Web service. Each Web service "advertises" its SOAP API using a mechanism called Web Services Description Language, allowing easy discovery of any service's capabilities.



Integration of Standards-Based Web Services

Web services provide an open, interoperable, and highly efficient framework for implementing systems. They are interoperable because each piece of software communicates with each other piece via the standard SOAP and XML protocols. This means that if a developer "wraps" an application with a SOAP API, it can talk with (call/serve) other applications. Web services are efficient because they build on the stateless (loosely coupled) environment of the Internet. A number of nodes can be dynamically connected only when necessary to carry out a specific task such as update a database or provide a particular service.

While conceptually the basic computer components of a Web services system are still clients and servers, it is important to recognize that the network connections are dynamically created "just in time" and, therefore, do not require the overhead of "state full" networks. These networks can be implemented in open as well as secure environments.

Web Services and GIS

This loosely coupled architecture provides a new and promising solution for implementation of complex collaborative applications such as a distributed GIS. In some ways, the integration of GIS and Web services simply means that GIS can be more extensively implemented, and people will be able to take mapping, data, and geoprocessing services from many servers and integrate them into a common environment. Unique to GIS-based Web services is the ability to not only connect and interoperate but to integrate data using the unique properties that are inherent within GIS itself (i.e., data integration and fusion based on geographic location).

Web services enable the realization of some of the big visions for GIS that have been formulated throughout a number of years. These include

- The implementation of a spatial data infrastructure, that is, a distributed network of shared data stores and applications including multiagency and multiorganization participation.
- The fusion of GIS applications, that is, the ability to bring together multiple GIS applications using geography as the integrated framework. For example, a local government will be able to continuously maintain and update its land records while serving them into other parts of the organization as well as to external organizations. A utility company could then directly use the basemap of the local government as a replacement for its own basemaps for facility data. A utility company could also serve its facilities data back to a local government for use in permitting and land use planning. This type of interorganizational synergy will dynamically accelerate the use of geographic information everywhere.

GIS fundamentally involves the integration of data from multiple sources. The Web services architecture establishes a particular type of relationship between service providers and consumers of information that nicely supports the dynamic integration of data, key to creating a spatial data infrastructure.

ESRI and Web Services

With the introduction of Web services, distributed multivendor GIS services can be dynamically integrated into applications using the interoperable standards of XML and SOAP. This level of integration is already working on the desktop.

ESRI's ArcGIS Desktop products (ArcView, ArcEditor, and ArcInfo) can already fuse multiple ArcIMS services (e.g., map/image overlay). In the near future, ArcIMS will support integration of these GIS services on a Web service tier. That means an applications developer can take two or more distributed GIS services (i.e., mapping, geoprocessing, or data streaming) and build a new application anyone can use. This Web tier environment is based on the XML/SOAP standards and, therefore, provides a standards-based framework for integration of geographic information services from multiple vendors. ESRI's products will be able to dynamically integrate distributed GIS services from different GIS vendors that support Web Services standards. This framework is conceptually similar to the "direct read" API support now available on the desktop but promises to be more flexible.

The Geography Network

The Geography Network℠ (www.geographynetwork.com) is an example of a GIS implementation within a Web services framework. ESRI refers to this as the g.net architecture and provides products that enable users to create a full implementation of g.net architecture. ArcIMS provides both GIS services as well as broker services (metadata services). ESRI clients (ArcGIS Desktop, ArcExplorer, MapObjects—Java, ArcPad, etc.) can integrate one or more of these Web services within existing applications.

GIS services are now being served individually (e.g., a map service, a feature streaming service) via ArcIMS. One of the key concepts for the next generation of our product is the notion that individual GIS services can be server based. In turn, these new applications can be served to Web browsers and other lightweight mobile clients. In this architecture, the server can hold the key business logic of an application and provide fast and centralized services to end users.

WMS and WFS Connectors

As an example of our commitment to making these services available and useful, ESRI is creating OGC-supported extensions to our ArcGIS Desktop products, ArcIMS, and ArcExplorer. The first of these are the Web Map Service (WMS) and Web Feature Service (WFS) connectors for ArcIMS. The OGC WMS connector enables ArcIMS to provide Web map services that adhere to the OpenGIS® Web Map Service Implementation Specification. The OGC WMS connector produces maps of georeferenced data in image formats (PNG, GIF, JPEG) and creates a standard means for users to request maps on the Web and for servers to describe data holdings.

The OGC WFS connector enables ArcIMS to provide Web feature services that adhere to the OpenGIS Web Feature Service Implementation Specification. The connector provides users with access to geographic (vector) data, supports query results, and implements interfaces for data manipulation operations on Geographic Markup Language (GML) features served from data stores that are accessible via the Internet. GML is an OpenGIS Implementation Specification designed to transport and store geographic information. It is a profile (encoding) of Extensible Markup Language.

To download the OGC connectors for ArcIMS, visit the ESRI Interoperability Technology Download Center at www.esri.com/standards.

Standards Organizations

Related to the efforts outlined above, ESRI supports and participates in 12 major international and U.S. GIS standards and interoperability organizations. We serve in leadership roles in many of the programs, initiatives, and specification efforts. For example, we are on the OGC Board of Directors, Planning, and Technical Committees, and participate in the test beds, pilot projects, and specification products.

Some of the organizations ESRI works with include

- ISO—International Organization for Standardization
- OGC—Open GIS Consortium
- W3C—World Wide Web Consortium
- ANSI—American National Standards Institute
- IHO—International Hydrographic Organization
- WS-I—Web Services Interoperability Organization

- LIF—Location Interoperability Forum
- WLIA—Wireless Location Industry Association
- FGDC—Federal Geographic Data Committee
- GSDI—Global Spatial Data Infrastructure
- CEN—European Committee for Standardization
- DGIWG—Digital Geographic Information Working Group

Conclusion

ESRI has made major investments in the development and implementation of open GIS standards, not only to serve our own customers but also to promote sharing geographic data across all GIS platforms. We believe our continuing investments in Web services will result in the most open and interoperable GIS solution ever deployed. ESRI constantly looks to its customers for feedback regarding the value of its initiatives and is especially interested in how our customers are leveraging our investments in interoperability to meet their GIS needs and solve real-world problems.

More Information

For further information on standards and the ESRI family of products, visit www.esri.com/standards.

For more than 30 years ESRI has been helping people manage and analyze geographic information. ESRI offers a framework for implementing GIS technology in any organization with a seamless link from personal GIS on the desktop to enterprisewide GIS client/server and data management systems. ESRI GIS solutions are flexible and can be customized to meet the needs of our users. ESRI is a full-service GIS company, ready to help you begin, grow, and build success with GIS.

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