INTEROPERABLE IMAGE DATA ACCESS THROUGH ARCGIS SERVER

Qian Liu

Environmental Systems Research Institute
380 New York Street
Redlands, CA92373, U.S.A - qliu@esri.com

KEY WORDS: OGC, Standard, Interoperability, Web Service, Web Coverage Service, Arcgis Server

ABSTRACT:

As networking and data storage technologies advance, web services have become a commonplace for data mining and sharing in an e-business model. Compared with business information, geospatial information is normally overwhelmed by the sheer volume of data. There has been a great need for the integration of web services and geospatial information to provide a platform for geospatial information dissemination. In recent years, geospatial web services have emerged into the mainstream for interoperable spatial information access over the network. The interoperability enabled by the standards makes web service more attractive considering the diversity in geospatial information. The OGC, a major player in standardizing geospatial web services, has initiated several web service specifications for data interoperability over the past few years. As an industry leader in GIS, ESRI has always been committed to keep up with industry standards and provide openness in its products. As an example, ESRI ArcGIS Server [1] is fully compliant with OGC WMS, WCS, and WFS specifications in addition to other industry standards. This paper will review the WMS and WCS specifications implemented in ArcGIS Server 9.3 for interoperable imagery data access as well as outline the process to publish and consume such services.

1. INTRODUCTION

Image data are being acquired by sensors constantly and the data volume keeps growing by the minute. Proper handling the large amount of imagery data has imposed a great challenge to many data providers, vendors. This also holds true for large organizations and enterprises who keeps a large collection of imagery data and want to share the information with people inside and outside of the organization. To complicate the situation, data obtained from various sources may also come in a variety of forms and different characteristics, and they are not necessarily in the form that the consumers require in their GIS applications. When it comes to end users, what they really need is timely and easy access to the information. It becomes irrelevant to them as what the data sources or data forms are, and their only interest is how the data can be delivered as they have requested to fit their needs and be utilized in their applications, either for visualization or analysis. Traditional order and delivery mechanism of data via media has proven to be an inefficient way for the consumers in this fast-paced internet dominated information world. To extract geospatial information with the traditional approach may involve time-intensive operations such as data conversion, data duplication and data preprocessing to satisfy the user's needs. This inevitably delays the use of the data and reduces the value of the data as the data ages.

Web service technology has matured in the past few years. The major attraction of web service is the interoperability that is enabled by the standardization of data/message exchange [2]. Interoperability allows the collaboration of data sharing across various systems over different platforms. Web service overcomes the shortcomings of the traditional data dissemination approach and benefits tremendously to the geospatial community. The benefits of using geospatial web services include but not limited to: reduction of duplication of large amount of data, resource sharing, independent service implementations, independent platform and operating systems, simple interface specified by the standards, and timely on-demand data delivery. All these characteristics are making the consumption of geospatial information easier than ever. There is no doubt that geospatial web service has brought the management, processing, and dissemination of geospatial information to a new era.

The Open Geospatial Consortium (OGC) [3] is a non-profit, international, voluntary consensus standards organization whose focus is mainly on the development of standards for geospatial and location based services. Standards are increasingly becoming a key point for organizations that distribute and share data over the Internet. As a governing organization of geospatial standards, OGC has been initiating and promoting publicly available geospatial web standards. These standards provide a common ground for interoperable operations between different geospatial information systems. Over the past few years, OCS has successfully executed several standards initiatives that have lead to a few web service specifications including Web Map Service (WMS), Web Coverage Service (WCS), Web Feature Service (WFS), Web Catalog Service (CW-S), and etc.

Environmental Systems Research Institute (ESRI), the leading GIS software company in the world, has always been concerned with interoperability in its products, and the priority is even higher for its server product. ESRI is committed to building open and interoperable commercial off-the-shelf software products. ArcGIS Server, the server GIS in ArcGIS product family, has been adapting and implementing standards as they become available. In addition to the improvements on scalability, manageability, and usability, ArcGIS Server has been enhanced to support more open standards in ISO, W3C, and OGC in its latest release of version 9.3. ArcGIS Server 9.3 supports numerous OGC specifications that allow users to publish their data services in an interoperable manner. The

server is capable of authoring various data sources and making the data available for web access. The enhancements in managing and serving imagery data in ArcGIS Server provide a unique and efficient way to interoperate imagery data.

2. OGC WEB SERVICE STANDARDS

A few years ago, OGC initialized the OGC Web Service (OWS) specification which specifies the web service standards for access, integration, visualization, analysis of geospatial information across the web. OWS is one of OGC's many initiatives for addressing the lack of interoperability among geospatial systems. OWS Specifications provide standards for implementing interoperable, distributed geospatial information processing software systems for a user to easily share geospatial information and services with others. The standards have been agreed and adopted as industry standards and supported by many organizations and enterprises. With these standards it is possible for different geospatial systems to communicate with each other over the web using common languages such as XML or HTTP. It also provides an interoperable environment for web-based data access to multiple online resources, Among the OGC web services specifications, Web Coverage Service and Web Map Service are particularly in the interests of interoperable image data access over the web.

2.1 OGC Web Coverage Service

The OGC Web Coverage Service (WCS) provides an open specification for sharing imagery data on the Web [4]. The imagery data made available through WCS services are called coverages. WCS provides interoperable interface for accessing multi-spectral, multi-temporal imagery data from multiple data sources or services. WCS is a true data service and deliver the data that is intact. Encoded in the forms that keep the original values, the data returned from a WCS request can be used as input for analysis/modelling as well as visualization.

The OGC WCS specification defines three operations: GetCapability, DescribeCoverage, and GetCoverage.

The GetCapabilities operation returns an XML document with service-level metadata including the server capabilities and a brief description of available coverages served in the service. With these pieces of information, it is possible for the client to formulate a simple GetCoverage request (e.g. request a subset of the coverage with given extent) to fetch the data to fit the user requirements. However a full description of the coverages may be obtained in order to make finely tuned requests, such as request of a subset of ranges.

The DescribeCoverage operation returns a full description of one or many coverages specified in the request in an XML encoded document. The response describes the properties of the coverages including spatial domain, range domain, pixel resolution, supported interpolation method, supported output raster format, and supported output coordinate systems. The information helps generating complicated GetCoverage requests to extract data using the specific properties of the coverage in its request parameters.

The GetCoverage operation returns the multidimensional data to the client as it is requested. When making the request, the client is responsible to specify spatial extent, range/temporal subset, raster resolution, coordinate system and the encoding format for the returning data. It is the service provider's responsibility to extract the data from the resources, process it on-the-fly if needed in client's specifications, organize the data in the specified format, and return the data to client.

2.2 OGC Web Map Service

The OGC Web Map Service (WMS) specification provides the mechanism to interchange geospatial data in the form of a map [5]. It is possible to fuse a collection of data layers in a map and serve the fused map as WMS service. What the client gets is a picture in a format such as JPEG, PNG, BMP, or GIF that are rendered from the source data. Unlike WCS where the returned coverages are intact, WMS provides a representation of the data, but not the data itself. Therefore it is not valid source for modelling, but rather for visualization.

WMS specification defines two required operations and one optional operation.

Similar to WCS, the GetCapabilities operation return a description of the capabilities that the service supports and a brief description of each data layer in the service.

The GetMap operation returns a picture depicting the map in a picture format specified by the client. There is not much variation in GetMap request for map with imagery data other than the request extent.

3. ARCGIS SERVER OVERVIEW

ArcGIS Server is the GIS server product in ESRI's ArcGIS product family. It is a complete and interoperable server-based GIS product. It comes with out-of-the-box end user applications and services for spatial data management, visualization, and spatial analysis. ArcGIS Server allows you to publish your content and analyses as geospatial web services to share the use of the resources across an enterprise or across the web. The ability to sharing geospatial resources enables the service providers to manage resources in a centralized, handle multiple user access, and provide most up-to-date information. Considering the characteristics of imagery data, this really makes a difference. To be able to access the services published through ArcGIS Server, the clients do not need install any GIS software or store the resources. All services are consumable within a web browser or custom applications. In addition to providing access to GIS resources over the network, ArcGIS server also provides access to GIS functionality contained in the resource. GIS resources on a GIS server may be utilized in various ways depending on the user level and purpose. Developer type users may use the resources directly to build web applications while other people may just browse the map in a web application.

3.1 Types of Services

As any server products, sharing data through web services involves preparing data resources, publishing the resources as services and serving the services for a wide variety of clients to consume. The client uses various protocols to access the service (Figure 1). At release of 9.3, ArcGIS server hosts a list of core service types that can be created from a list of GIS resources (Table 1). Each service type is targeted for specific resources and use of the resources by the client applications [6].

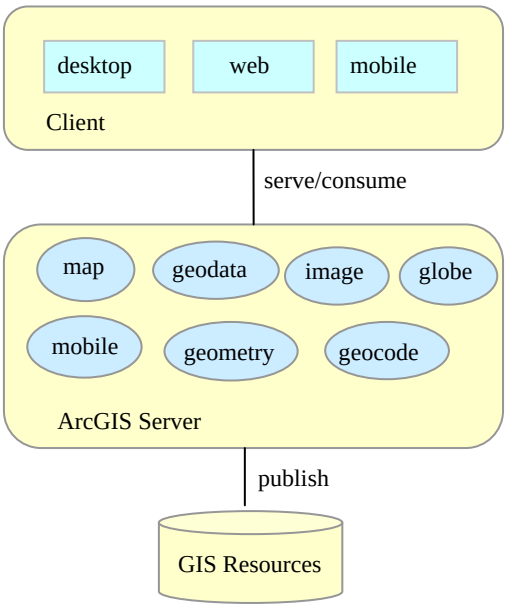

Figure 1. ArcGIS Server Architecture

Service Type	Required GIS Resource
Map service	Map document
Geocode service	Address locator
Geodata service	Database connection
Geometry service	
Geoprocessing service	Map document with a tool layer or toolbox
Globe service	Globe document
Image service	Raster dataset or layer or compiled service definition file

Table 1. ArcGIS Server Service Types

As far as the interoperable access of imagery data through OGC standards is concerned, map service, geodata service and image service are of the particular interests. And the discussion will be focused on these three types of core services.

A map service is the most common type among all the ArcGIS services. It allows publishing a map document for viewing and sharing the map with others, optionally a map service also supports data editing, modeling and mobile service. A map document may contain all sorts of geospatial data layers such as raster layer, feature layer, geoprocessing tool layer, and etc. Map services are designed to work in GIS applications, web applications, mobile applications, and mashups.

A geodata service provides the access to a geodatabase through networks using ArcGIS Server. Some organizations store large collection of preprocessed geospatial data in geodatabase to take advantage of a geodatabase. These data are easily made available to others through ArcGIS Server.

An image service allows you to access raster data resources through web services. The raster data resources include flat raster files, raster data stored in a geodatabase, a collection of raster datasets, raster layers which may have been rendered in certain way, and compiled service definition file generated using ArcGIS Image Server extension. Moreover, raw imagery data are processed on-the-fly to save preprocessing time and storage space for intermediate results. Image services are optimized for image management, process, and dissemination with a centralized repository and administration using ArcGIS Server.

In ArcGIS Server architecture, each core service supports a list of capabilities. By enabling capabilities available to the services, additional services with the same resource are created. Interoperable data access is achieved through these secondary services.

3.2 Capabilities

On top of ArcGIS Server services a series of capabilities are available to define ways for the clients to use the service. The capabilities are designed to interoperate with other systems and target different types of client. For instance, an OGC service is appropriate for the clients that are compliant with OGC standards which allow the client and the server to communicate using the same interface. In the user's view, these capabilities are separated services and a core server may have one or more extended services. The available capabilities vary for a resource depending on the type of the resource.

A map service extends mapping, WCS, WMS, KML and several other capabilities (Figure 2). The map service is accessed via SOAP protocol to be used in desktop GIS applications or web applications. The REST end point of the map service allows the content in the service to be accessed and interoperate with other web services in a mashup environment.

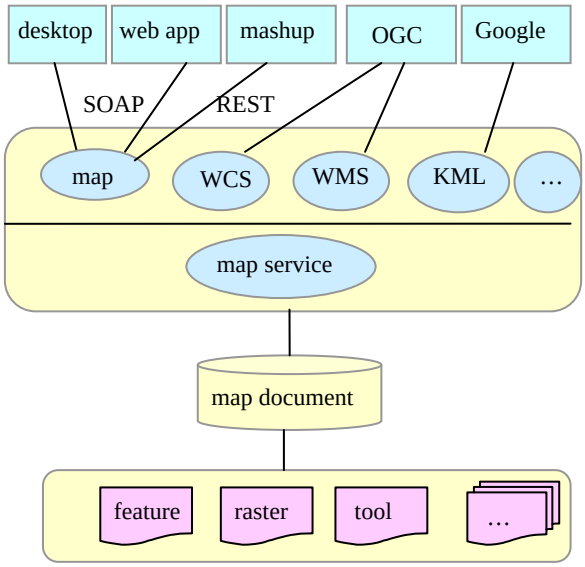

Figure 2. Map Service Capabilities

Geodata capability enabled on a geodata service provides the access to the geodatabase for remote operation on the database, and WCS capability is also available for interoperable raster data access in the geodatabase over the internet.

Image services are optimized for management and dissemination of imagery data on the web, the capabilities are

designed for optimal and interoperable delivery of the resources. Similar to a map service, imaging capability propagate SOAP and REST protocols for desktop or web applications to access the service and to be used for mashup with other web services. Open source clients are able to consume image services through OGC WMS or WCS specification. And as a standard for Google earth, the KML capability enables an image service to be incorporated into Google earth seamlessly.

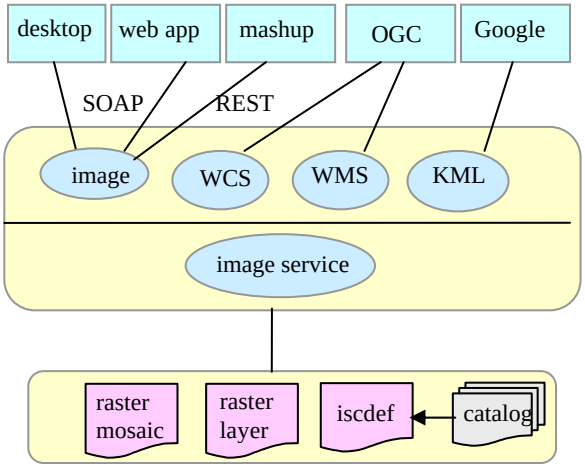

Figure 3. Image Service Capabilities

3.3 OGC WCS Implementations

ArcGIS server implements OGC WCS according to the specification versions 1.0.0, 1.1.0 and 1.1.1. Even though version 1.1.x differs from version 1.0.0 greatly, the implementation details are handled on the server side and are totally hidden from the clients. As long as the clients issue request in accordance with the specification for the specified version, the server will return the data in the requested form.

3.3.1 Data sources

The characteristics of imagery data that makes it unique is not only the data volume, but also the variety of forms or states that the data may come in. The ultimate goal of ArcGIS Server is to make data in all forms and states available for access by web coverage client through WCS, from raw data acquired from sensors, to georectified scenes, to preprocessed mosaic; from single band panchromatic image, to digital elevation dataset, to colored satellite images; from single image to a collection of imageries. It is very likely that imagery data are encoded in various raster formats, either to suite the content of the data or to comply with proprietary requirements. ArcGIS Server is capable of serving imagery data in some 20+ raster formats such as TIFF, JPEG2000, GRID, Geodatabaase, and other sensor specific formats.

3.3.2 Output formats

A few output coverage formats are specified in the OGC specifications, ArcGIS Server has added more to the list. For the purpose of data analysis and processing, the uncompressed raster formats (GeoTIFF, NITF or HDF) should be requested. These formats ensure the data values unchanged from the source to the client. However, as a tradeoff, the time spent on retrieving data may be longer than that of compressed format since more data has to be transported over the web. On the other hand, JPEG, JPEG2000, and PNG formats encode the data values in a compressed manner where the values that the clients receive do not guarantee to be the same as the source. Considering less data are being transferred, the performance is better compared to uncompressed formats, and in most case the quality is good enough for mapping applications. Limitations do exist for requesting output coverage in a compressed format, for instance, a digital elevation data source can not be encoded in JPEG format since the elevation values are normally not integer values. As to what format to choose, it is all dependent on the clients' need and the use of the data.

3.3.3 On-the-fly data processing

Data sources may not always provide the exact information that clients need. It is not uncommon that processing of source data is required to produce the data that fit the client's need. More often service providers want to serve the imageries as they become available from the sensors for immediate consumption. ArcGIS Server is capable of processing the raw data source on-the-fly so that the processed data are available for clients to access without preprocessing and postprocessing. Processing on-the-fly doesn't only save time on preprocessing but also save storage space required for intermediate data that would need to be stored otherwise. ArcGIS Server provides a spectrum of processing capabilities that are normally available in image processing packages, such as geometric correction, radiometric enhancement, seamless mosaicking and etc. Furthermore it is possible to design a chain of processes that encapsulates a list of processes and apply it to a service in an optimized way. The other benefit of on-the-fly processing is the polymorphic productions or services on the same source data sets. Several services can be served from the same resources by simply specifying different processes.

Mosaic on-the-fly is one of the most common operations on a service that consists of a collection of images within the same area of interest, and to complicate the case, in some cases the source data are even collected from different sensors and possess different properties such as format, value type, and even coordinate system. Those images could have overlaps as well. In order to return a seamless image to the clients, the server has to define a logic for mosaicking method and also what source data to retrieve and execute it when the data is requested. There are quite a few options on how the mosaicking process works on such a collection. For rotated tiles with black background, seamlines generated along the border between the image and the background eliminate discontinuity across tile boundaries and are used to create a seamless mosaic; for overlapped images (time series datasets), the order by attribute option offers the flexibility to view certain images according to the attributes. All on-the-fly options are defined at the time of service creation.

3.3.4 Scale dependency and resampling

The use of WCS coverage data varies from client to client. The native resolution or scale of the data source for the service is not necessarily the resolution that the client would like to utilize in their application. Extracting low resolution data from high resolution imagery requires resampling the high resolution data which involves heavy calculations. However, if the source data contains a stack of layers in which each layer stores data appropriate for a certain resolution or scale, when the client

makes a request for a specific scale the server finds the matching layer and return it. In the case that the requested scale do not match any of the layers in the stack, the layer with closest scale is resampled to the requested scale. In the process of resampling, ArcGIS Server provides options for interpolating of the data such as nearest neighbor, bilinear and cubic.

3.3.5 Subsetting

One important requirement for a WCS server is the ability to supply a subset of the multi-dimensional data to the client. Data can be subsetted in spatial, spectral, temporal domains. In spatial domain subsetting, the server clips the data to the spatial dimension specified by the client and returns the result to the client. In non-spatial domain subsetting, the client sends request with a range or a distinct list of spectral bands or time periods and the server subsets the data accordingly and arranges the data in requested formats to return to the client.

3.3.6 On-demand reprojection

To make immediate use of WCS coverage data in the client's application without further processing, the client normally request data in a spatial reference system that fits the application best. WCS specification allows the client to request data in a dimension within one spatial reference system and have the data returned in a different one. And either of these two spatial reference systems is required to be the same as the data in the service. ArcGIS Server handles the multiple projection requests easily with on-the-fly process. The request boundingbox is first reprojected to the spatial reference of the source data and used to subset the pixels, the arrays of pixels is then reprojected to the spatial reference of the returned coverage as specified and the result is returned. Considering the rich set of spatial references supported by ArcGIS products, the WCS coverage can be returned in one of the many supported spatial references.

3.3.7 WMS Implementations

Compared to WCS implementations, WMS implementations are simpler for image data related services. The same sources for WCS service are applicable to WMS service as well, in addition to map documents. The returned maps from WMS services are predominately for viewing and mapping and they are returned as pictures encoded in JPEG, PNG, GIF, and BMP formats. Bound to its limited use, there is not much flexibility for WMS requests other than spatial subsetting. The versions of specifications that are currently available and implemented by ArcGIS Server are 1.0.0, 1.1.0, 1.1.1, 1.3.0.

4. PUBLISHING IMAGERY DATA AS OGC WEB SERVICES IN ARCGIS SERVER

It is always a good practice to study the data sources and the intended use of a service before preparing and publishing the data as a web service. The uniqueness of imagery data requires even more considerations. Publishing a data source for sharing is an easy task and can be done in a few simple steps in ArcGIS Server. However how to publish a service effectively and efficiently to meet the clients' needs is more challenging.

Publishing any GIS service first requires the creation of the GIS resource. In order to create an OGC WCS or WMS service, one of the following resources has to be prepared:

- A map document
- A raster mosaic
- A raster layer
- A complied service definition
- A geodatabase

Once one of these GIS resources is ready, it can be published as a core ArcGIS Server service with WCS or WMS capabilities enabled.

When preparing a GIS resource, there are many things to be considered. There is not one type of resources that works well with all sorts of imagery data sources. Let's take a look at a couple of scenarios to see the process of creating an appropriate resource.

4.1 Preprocessed Raster Mosaic

In some large organizations, a set of standard image processes has been established to process the raw data acquired from the sensors and produce unified output products for multiple purposes across the whole organization. The processes vary from geometric correction, radiometric correction, to other enhancements. The processed small individual tiles are eventually mosaicked into a seamless dataset by area of interest, data source type, or other criteria. These data are intended not only for web access through web services but also for use in other GIS application systems. Most often the standardized data products are archived and stored in a central repository for easy management, some of them are maintained in a geodatabase. With no need for processing, the data can be published directly as an image service with WCS capability enabled, and one such WCS service contains one mosaicked dataset. And if there are many mosaicked data to be served, there will be many image services. To take advantage of the data stored in a geodatabase, one single geodata service can be created to include all the datasets in the geodatabase. With this approach, one WCS service provides access to multiple datasets as WCS covereages. The client experience is universal in retrieving WCS coverage published through an ArcGIS Server WCS service despite of the difference in the type of the core service on which the WCS capability is enabled.

4.2 Raw Image Data Collection

Empowered with server side processing capabilities, serving raw imagery data avoids taking lengthy time in preprocessing, and taking disk spaces to store intermediate and end results. To some organizations without the luxury of hardware resources and database management systems, this is more attractive and practical. One other advantage that can not be overlooked is the timely use of the data and this provides invaluable information for real time operations in emergency situations such as fire, flood of other natural disasters. Setting up a service with processing on-the-fly capability requires the ArcGIS Image Server which is an extension of ArcGIS Server.

ArcGIS Image Server enables the creation of image services that can include large numbers of imagery data that may be in different formats, projections, and at different resolutions. One of the key features of ArcGIS Image Server is that it supports image data in its native format and does not require any extra data conversion to a specific format. In addition, the data may be in different forms such as preprocessed product, scanned

maps, or raw satellite images. Utilizing the server's processing data source, each with different radiometric processing, geometric processing, mosaicking rules, and compression options.

The process of publishing a large collection of imagery data and serving it as one seamless service includes creating an image service definition, compiling the definition, and publishing the compiled service definition (iscdef) as an image service with WCS capability enabled. At the time of service definition creation, the source data collection and process chains can be defined, for the instance of a service which contains collections of multiple spectral datasets and corresponding panchromatic datasets with higher resolution, a pansharpening process can be applied to the service to enhance the multiple spectral datasets. The built-in intelligence optimizes the service by building a comprehensive metadata for each dataset in the collection. The metadata records information and instructions for the server to extract and process only the necessary data to construct a mosaic and send back to the client at the resolution as requested. If the source data do not contain reduced resolution layers that are necessary for requests at resolutions lower than the source data, overviews can be generated in place of reduced resolution layers. The overviews are treated as datasets the same way as the source datasets and optimized for fast data retrieval. Any processes specified on the service definition are applied on-the-fly when the client makes a request. In order to serve the resource, the service definition has to be compiled to a compiled service definition file which is a valid GIS resource for an image service.

4.3 Raster Data for Viewing

This is a simple case where the purpose of the service is to view or use the service as a background for mapping. A map document offers ranges of tools and options to enhance visualization qualities. And it is possible to integrate or fuse all types of data types such as feature data and image data together to make the appearance more pleasant. Since the service will not be used in any analysis, the data can be compressed to improve data transfer performance. The best approach would be to create a map document with necessary layers rendered in a way the client requires and publish it as a map service WMS capability enabled. In the case that large volume of data is involved in the map document, performance can be optimized by creating map caches.

Covering all use cases in this paper is not possible. The key of serving available data sources in an optimal manner is to understand the data and expectation from the clients and choose the best approach.

power, multiple image products can be generated from a single

5. CONSUMING ARCGIS SERVER OGC WEB SERVICES

OGC web services can be consumed in any clients on the web that are compliant with OGC specifications. A Web browser is the simplest client of WCS or WMS services. WCS/WMS requests can be issued through HTTP by supplying a service URL and request parameters, and the responses or exceptions are returned through the browser. It is worth to mention that the GetCoverage request parameters in WCS 1.1.x are completely different from that of WCS 1.0.0, and requests that work in WCS 1.0.0 version may not work in version 1.1.x.

There are a few open OGC clients that provide easy access to view any OGC services. For more sophisticated users, the web services can be used as a data source for analysis in a desktop GIS application. ESRI ArcGIS desktop can act as clients for these OGC services.

6. CONCLUSIONS

Geospatial web services solve a series of problems that have prevented efficient dissemination and consumption of large amount of imagery data. The interoperability standards by OGC opened the door to a wider audience and brought the geospatial information community together. ESRI ArcGIS Server, empowered with some key components such as ArcSDE and ArcGIS Image Server, offers a complete solution for data management, processing, and serving for a very large volume of imagery data. Comprehensive server side processing capabilities and rich supports for a good variety of data sources make it easy to publish and serve any data as web services in ArcGIS Server. Implementations of OGC specification facilitate the interoperable access of imagery data served through ArcGIS Server.

REFERENCE

[1] ESRI ArcGIS software, http://www.esri.com/software/arcgis

[2] Hilton, B., 2007. *Emerging Spatial Information Systems and Applications*. Idea Group Inc, USA, pp. 2-12.

[3] OGC, http://www.opengeospatial.org/

[4] Whiteside, A. & Evans, J., 2007. Web Coverage Service implementations. http://www.opengeospatial.org/standards/wcs. USA.

[5] Beauiardiere, J., 2004. OGC Web Map Service Interface. http://www.opengeospatial.org/standards/wms, USA.

[6] ESRI, 2007. ArcGIS Server Help (9.3), USA.