

Developing a Web Service-Compatible Map Server for Geophysical Applications

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ABSTRACT

The Open Geospatial Consortium (OGC) defines a number of standards (both for data models and for online services) that have been widely adopted in the Geographical Information System (GIS) community. In this paper we will describe our group's efforts to implement GIS services according to OGC standard specifications in accordance with the Web Services approach. This paper focuses on the Web Map Service (WMS), which we are coupling to problems in computational geophysics. Through the use of Web Services, we are able to integrate GIS services with other families of services, including information, data management, and remote application execution and management. We also describe WMS client building efforts that are suitable for integration with computational Web portals.

To be able to interact with non-Web Service versions of WMS, we also have built bridging service for our extended WMS. Since Web Service oriented WMS has a different request/response paradigm from non-Web Service versions, we have extended cascading WMS by adding request handler functionality. This kind of WMS behaves like both a cascading WMS and a proxy to handle different types of requests to overcome interoperability problems between different WMS systems.

Categories and Subject Descriptors

H.5 [Information Interfaces and Presentation]: Miscellaneous

J.2 [Physical Sciences and Engineering]: Earth and Atmospheric Sciences.

General Terms

Design, Human Factors, Standardization.

Keywords

Geographic Information Services (GIS), Web Map Services (WMS), Web Feature Services (WFS), Geographic Markup Language (GML), Web Services, Open Geospatial Consortium (OGC).

1. INTRODUCTION

Geographical Information Systems (GIS) introduce methods and environments to visualize, manipulate, and analyze geospatial data. These methods and environments have some interoperability problems. The nature of the geographical applications requires seamless integration and sharing of spatial data from a variety of providers. Interoperability of services across organizations and providers is a main goal for GIS and also Grid computing [15, 27].

To solve the interoperability problems, the Open Geospatial Consortium (OGC) has introduced standards by publishing specifications for the GIS services. OGC is a non-profit, international standards organization that is leading the development of standards for geographic data related operations and services. OGC has variety of contributors from different areas such as private industry and academia to create open and extensible software application programming interfaces for GIS [1].

GIS services, such as defined by the OGC, are part of a larger effort to build distributed systems around the principles of Service Oriented Architectures (SOA). Such systems unify distributed services through a message-oriented architecture, allowing loose coupling, scalability, fault tolerance, and cross-organizational service collections [25]. Web Service standards [3] are a common

implementation of SOA ideals, and Grid computing has converging requirements [15, 27]. By implementing Web Service versions of GIS services, we can integrate them directly with scientific application grids [11].

This document gives the details about the design and architecture of our Web Service refactoring of OGC specifications for the Web Map Service. This is part of a larger effort by our group to investigate translations of GIS services into Web Service standards [2]. Some earlier work in this area is reported in WMS [13]. In these documents they define standard WSDL description of the service interfaces.

In this document we first give a brief explanation of the GIS technology and related terminology. After briefly describing GIS, we give the definitions of some commonly used terms in the GIS. In Section 3, we describe general architecture for developing Web Service-Compatible mapping services. Under this title as subtopics we describe contributions of the Web Services to the GIS services, technical challenges encountered during implementations, integrating Web Services into OGC compatible GIS visualization, creating valid requests to WMS services in case of using Web Services, bridging capability of cascaded WMS, other services involved in proposed visualization system and implementation details of WMS. In Section 4, future work is described. Section 5 is the conclusion.

2. GIS TECHNOLOGY and TERMINOLOGY

GIS is a collection of methods to visualize, manipulate, and analyze, geographically referenced data or geospatial data. The sources of geospatial data are digitized maps, aerial photographs, satellite images, statistical tables and other related documents. These maps are created in layers collected from distributed data sources (other map servers, feature servers, and so on). When combined with scientific applications, dynamically generated maps provide a powerful technique for conveying information. For example state boundary lines data can be analyzed and produce a map. In the same fashion, earthquake fault data can be analyzed to produce a map. GIS relates these two data sets by overlaying these two maps produced from the corresponding data and reach a conclusion about this relationship.

Below we list and give the definitions of some commonly used terms in the GIS. We will be using these terms often in the following sections [8].

Spatial Data: Spatial data pertains to the space occupied by objects. Example spatial data from the real world are cities, rivers, roads, states, crop coverage, mountain ranges etc. In the implementation these are represented by points, lines, rectangles, surfaces, volumes and etc. Spatial data have some common characteristics. These type of data are geometric data and in high

dimensions. These data can be either discrete (vector) or continuous (raster). GIS applications are applied on these types of data.

Geospatial Data: Geospatial data are spatial data associated with a location relative to the Earth.

Feature: A feature is an abstraction of a real world phenomenon. A digital representation of the real world can be thought of as a set of features.

Geographic Feature: A geographic feature is a feature associated with a location relative to the Earth. Geographic features are those that may have at least one property that is geometry-valued [7].

Vector Data: Vector data deals with discrete phenomena, each of which is conceived of as a feature. The spatial characteristics of a discrete real world phenomenon are represented by a set of one or more geometric primitives (points, curves, surfaces, or solids). Other characteristics of the phenomenon are recorded as feature attributes [21]. Usually, a single feature is associated with a single set of attribute values.

Raster Data: Raster data deals with real world phenomena that vary continuously over space. It contains a set of values, each associated with one of the elements in a regular array of points or cells. It is usually associated with a method for interpolating values at spatial positions between the points or within the cells.

Coverage – Coverage Data: OGC uses the term “coverage” to refer to any data representation that assigns values directly to spatial position. Coverage is a feature that associates positions within a bounded space (its spatiotemporal domain) to feature attribute values (its range). Examples include a raster image, a polygon overlay, or a digital elevation matrix [21].

The spatio-temporal domain of coverage is a set of geometric objects described in terms of direct positions. Commonly used spatio-temporal domains include point sets, grids, collections of closed rectangles, and other collections of geometric objects.

Spatial Reference System: A spatial reference system is a function which associates locations in space to geometries of coordinate tuples in a mathematical space, usually a real valued coordinate vector space, and conversely associates coordinate values and geometries to locations in the real world.

Temporal Reference System: A temporal reference system is a function that associates time to a coordinate (usually one dimensional points and intervals) and conversely associates coordinate geometries to real world time.

Spatial-Temporal Reference System: A spatial temporal reference system is an aggregation of a spatial system and a temporal system that it uses to associate coordinate geometries to locations in space and time. Normally, the aggregation uses orthogonal coordinates to represent space and time, but this is not necessarily the case in more complex, relativistic environments [22].

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3. ARCHITECTURE

3.1 Web Services for GIS

Web Services give us a means of interoperability between different software applications running on a variety of platforms. Web Services support interoperable machine-to-machine interaction over a network. Every Web Service has an interface described in a machine-readable format. Web Service interfaces are described in a standardized way by using Web Service Description Language (WSDL) [19]. WSDL files define input and output properties of any service and services' protocol bindings. WSDL files are written as XML documents. WSDL is used for describing and locating Web Services. Web Services are defined by the four major elements of WSDL, "portType", "message", "types" and "binding". Element portType defines the operations provided by the Web Services and the messages involved for these operations. Element message defines the data elements of the operations. Element types are data types used by the Web Service. Element binding defines the communication protocols. Other systems interact with the Web Service in a manner as described in WSDL using Simple Object Access Protocol (SOAP) messages.

SOAP [18] is an XML based message protocol for exchanging the information in distributed environment. It provides standard packaging structure for transporting XML documents over a variety of network transport protocols. It is made up of three different parts. These are the envelope, the encoding rules and the Remote Procedure Call (RPC) convention. SOAP can be used in combination with some other protocols such as HTTP. OGC compatible Web Services will be using SOAP over HTTP.

We have used Apache Axis for creating and publishing the Web Service. Axis takes care of the SOAP communication between server and the client. Axis 1 has proven itself to be a reliable and stable base on which to implement Java Web Services. Porting OGC services to Web Services will offer several key benefits, including:

Distribution: It will be easier to distribute geospatial data and applications across platforms, operating systems, computer languages, etc. They are platform and language neutral.

Integration: It will be easier for application developers to integrate geospatial functionality and data into their custom applications. It is easy to create client stubs from WSDL files and invoke the services.

Infrastructure: We can take advantage of the huge amount of infrastructure that is being built to enable the Web Services architecture – including development tools, application servers, messaging protocols, security infrastructure, workflow definitions, etc [13]. Some of these features are being developed by using Web Service infrastructure in Naradabrokering [28], message based middleware system, developed in CGL (Community Grids Lab.) at Indiana University. NaradaBrokering aims to provide a unified messaging environment that integrates grid services, web services, peer-to-peer interactions and traditional middleware operations. In the near future we will be utilizing these features in GIS visualization systems.

3.2 Integrating Web Services into OGC Compatible GIS Visualization

The WMS OpenGIS Specification specifies the implementation and use of the WMS operations (GetCapabilities, GetMap and GetFeatureInfo) in the Hypertext Transfer Protocol (HTTP) distributed computing platform. WMS operations can be invoked using a standard web browser by submitting requests in the form of Uniform Resource Locators (URLs). In the specification it is also said that future version may apply to other distributed computing platforms such as Web Services.

Web Services use SOAP for messaging. SOAP is an XML protocol. SOAP provides an envelope that encapsulates XML data for transfer through the web infrastructure (e.g. over HTTP, through caches and proxies). Most services (including our own) use the Remote Procedural Call (RPCs) encoding convention, but we expect more message-centric applications in the future with the release of Axis 2 and other implementations of SOAP Version 1.2. Serialization mechanisms are based on XML Schema data types [15].

3.3 Creating valid Request to WMS Services in Case of Using Web Services

In developing Web Service versions of the WMS, we have converted existing HTTP GET/POST conventions [4] into WSDL interfaces. We have encountered some minor technical problems in this conversion. Data binding frameworks such as Castor [16] or XMLBeans [17] take XML Schemas as input and produce java sources, greatly simplifying the coding work needed to process requests and responses. But one major problem with these frameworks is that sometimes it is not easy to find an object oriented correspondence of the XML Schema constructs. In such cases either the source codes can not be generated or generated source codes may not produce correct XML instances.

We chose the Castor data binding framework for our initial implementation. Unfortunately, some of the XML Schema types, such as substitutions and abstract types, used in OGC Schemas are currently not supported by Castor. We had to make several changes to make these schemas compatible with Castor Source Generator. Modifications are done just for the latest versions of the schema files of the GIS services. These modified schemas are available at <http://complexity.ucs.indiana.edu/~asayar/ogc/modified/>. We are currently investigating the use of XMLBeans as an alternative data binding framework.

Internal implementations of the WMS services are compatible with the current WMS specifications but service interfaces and the way to invoke services are different a bit different. Services are invoked through the SOAP over HTTP. Requests are created as XML documents and wrapped into body part of the SOAP request message. These requests are shown in Figure 1-3.

Invoking WMS operations should be according to specifications. OGC compatible requests to WMS are well defined in the WMS specifications [4]. Requests must have some parameters whose names, numbers, and values should obey the rules defined in the specifications to be OGC compatible. In this section we try to define these requests in the schema files to use them in accordance with the GIS services implemented as Web Services.

These schema files are created to be used during the invocation of operations implemented as Web Services at the WMS side [13]. Requests are created at the WMS Client side. Clients create these requests after getting required parameter from the user. When request is ready, client sends this request to WMS as a SOAP message. WMS has deployed Web Services for each service, getMap, getCapabilities and getFeatureInfo. Clients use client stubs created before to invoke these specific Web Services. All these services in WMS take one String parameter. This String parameter is request itself. These requests are actually xml documents in String format.

Below schema files displayed in Figure 1-3 are created with the help of Altova XmlSpy. They include all the elements and attributes of corresponding requests defined in OGC WMS specifications [4].

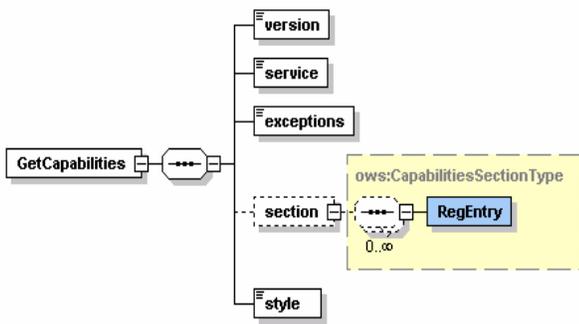


Figure 1 : GetCapabilities Request Schema.

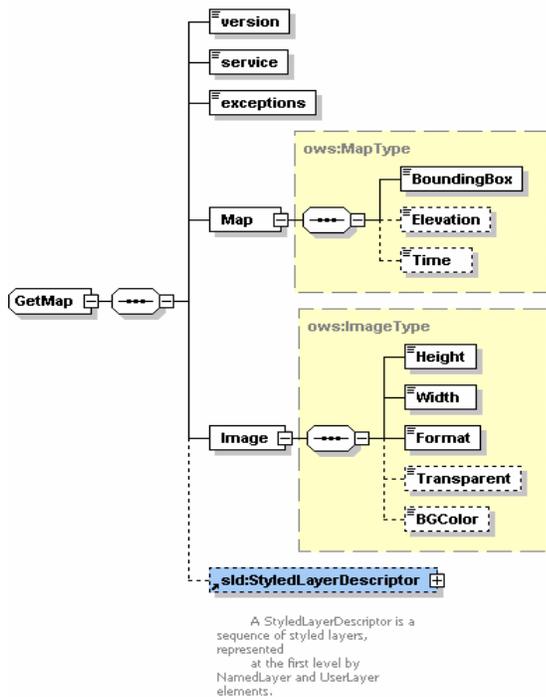


Figure 2 : GetMap Request Schema.

GetMap request is created for our WMS implementation. We have not implemented Styling capability yet. Styling capability will be added soon, for the current status and the future works please see the Section 4. WMS supporting styling are called SLD-enabled WMS. The Open GIS Consortium (OGC) Styled Layer Descriptor (SLD) specification [6] defines a mechanism for user-defined symbolization of feature. An SLD-enabled WMS retrieves feature data from a Web Feature Service [7] and applies explicit styling information provided by the user in order to render a map.

In our project since we have just implemented Basic WMS, we have not used elements related to styling in the WMS getMap requests. For defining styling in the getMap request we use StyledLayerDescriptor element. StyledLayerDescriptor has other sub elements and attributes.

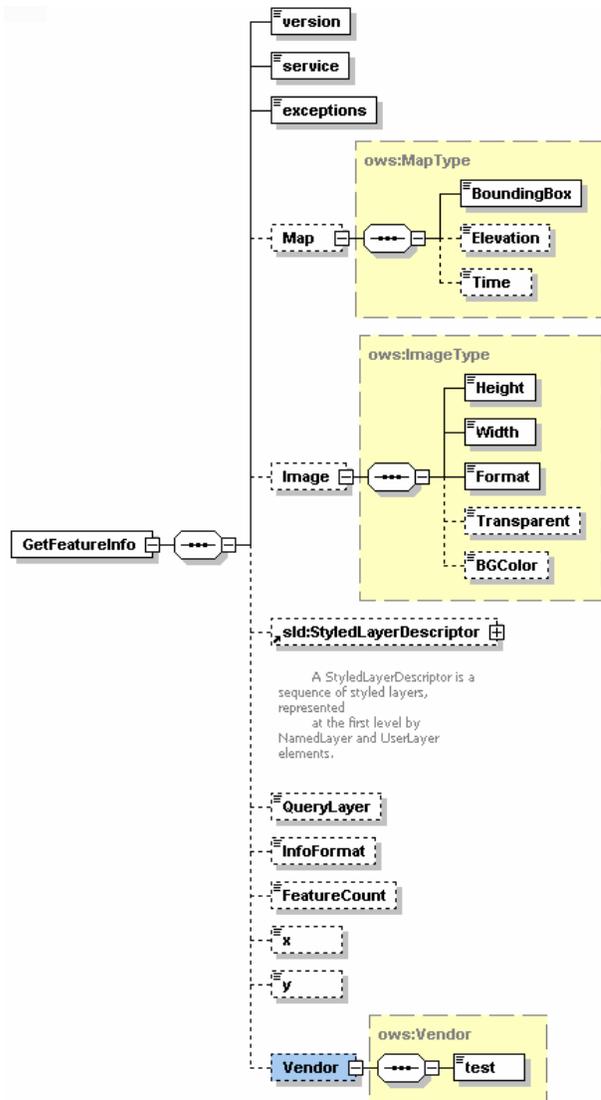


Figure 3 : GetFeatureInfo Request Schema.

3.4 Other GIS Components Involved in Proposed Visualization System

Our Web Service-compatible WMS depends upon Web Feature Service [32] and Information Services [33] to accomplish its required tasks. They are ongoing projects in CGL (Community Grids Lab.). This section briefly describes the WMS interactions with these other services.

A general picture of interactions between these three services is displayed in Figure 4. Initial invocations are displayed as black arrows.

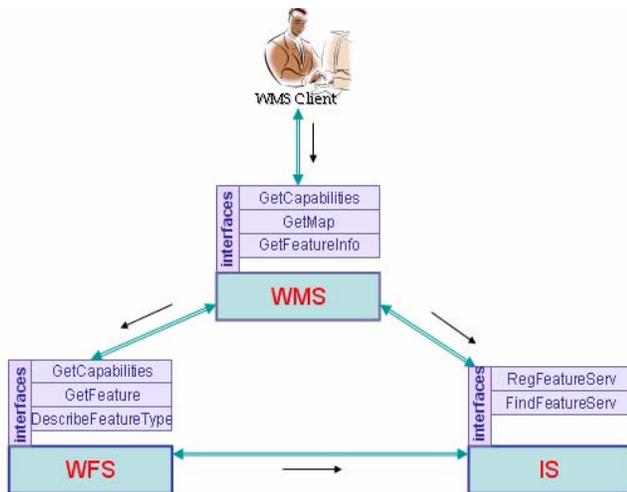


Figure 4 : Basic GIS Components involved in Visualization System. Abbreviations are expanded in the text.

3.4.1 Web Feature Service (WFS)

WFS instances store geospatial data and serve them upon request from clients. WFS clients include Web Map Servers and other WFS instances (in case of cascading WFS). WFS provide vector data, described in Section 2. Vector data are encoded in GML (Geographic Markup Language) [9], an XML encoding for the transport and storage of geographic information, including both the geometry and properties of geographic features.

According to OpenGIS WFS specification, basic Web Feature Services are getCapabilities, describeFeatureType and getFeature. If WFS is transactional than this WFS provides two more services. These are “transaction” and “lockFeature” services.

Since we have implemented basic WFS, WMS uses basic WFS services: getCapabilities, describeFeatureType, and getFeature. WMS sends a getCapabilities requests to WFS to learn which feature types WFS can service and what operations are supported on each feature type. The getCapabilities request can also be mediated by the aggregating Information Services (IS). WMS makes its request to IS to get a specific WFS address that provides needed feature. Please see Section 3.4.2 for the details about the interconnection between WMS and IS.

When any WMS client sends a getFeatureInfo request to WMS, WMS creates a getFeature request and sends it to WFS. The URL address of the WFS is found by using IS. After choosing an appropriate WFS, the WMS makes a getFeature requests to get feature data. A sample request is

shown in Figure 5 . The GML file encoded in XML is returned in a SOAP envelope as a response to this request. We have been using Apache Axis 1.2 [30] to handle Web Service issues. Developing and deploying web services, creating client-stubs, creating soap messages and invoking services are all handled by using Axis libraries. Our job is to make an interesting service implementation, described in Section 3.5 and 3.6

```

<?xml version="1.0" encoding="iso-8859-1"?>
<wfs:GetFeature outputFormat="GML2"
xmlns:gml="http://www.opengis.net/gml"
xmlns:wfs="http://www.opengis.net/wfs"
xmlns:ogc="http://www.opengis.net/ogc">
  <wfs:Query typeName="boundary_lines">
    <wfs:PropertyName>FNODE</wfs:PropertyName>
    <wfs:PropertyName>TNODE</wfs:PropertyName>
    <wfs:PropertyName>WORLD</wfs:PropertyName>
    <wfs:PropertyName>coordinates</wfs:PropertyName>
    <wfs:PropertyName>minx</wfs:PropertyName>
    <wfs:PropertyName>miny</wfs:PropertyName>
    <wfs:PropertyName>maxx</wfs:PropertyName>
    <wfs:PropertyName>maxy</wfs:PropertyName>
    <ogc:Filter>
      <ogc:BBOX>
        <ogc:PropertyName>coordinates</ogc:PropertyName>
        <gml:Box>
          <gml:coordinates>-155,28 -120,50</gml:coordinates>
        </gml:Box>
      </ogc:BBOX>
    </ogc:Filter>
  </wfs:Query>
</wfs:GetFeature>
  
```

Figure 5 : Sample GetFeature request from WMS to WFS.

3.4.2 IS (Information-Discovery Services)

An OGC Catalog [14] is a collection of descriptive information (metadata) regarding the data stored in a geographic database. OGC catalog service is specific to OGC domain. Each GIS Service provides access to geographic data. An important factor that characterizes GIS Services is the metadata about the data. Thus, metadata act as properties that can be queried and requested through catalog services. A catalog service provides discovery of GIS services through the metadata of the data that these services provide. The OGC Catalog Service is provides useful GIS metadata and registry capabilities, but we are interested in making several extensions. For instance, the registry should also allow discovery of services based on non-functional requirements of services such as Quality of Service attributes. Also, OGC Catalog Service should be consistent with other existing and more general registry models such as UDDI or ebXML.

To overcome these limitations, we utilize a Registry model which is being developed in CGL as a general registry model for Web Services, Fault Tolerant High Performance Information Services (FTHPIS) [33]. An Information Service (IS) is a general service registry and discovery model based on UDDI specifications [34]. UDDI is WS-I approved specifications, in other words, it is inter operable with other Web Service based standards. An IS provides both publishing and discovery services for of Web Services and (WS-Context) [23] contextual information of GIS Services. Since

IS stores both functional metadata (metadata about GIS data) and non-functional metadata (metadata about Quality of Services of data, such as high throughput), it provides more complex query abilities when discovering GIS services.

A map server interacts with Information Services to dynamically discover available Web Feature Services. We can summarize the interaction between an Information Service, Web Feature Service and Web Map Server as following.

All GIS Web Feature Services are expected register themselves into an existing IS in order to be "discoverable". Once the registry is completed, the IS starts interacting with WFS to retrieve more information about their capabilities. So, IS stores information about the functionality's of each WFS.

A Web Map Server queries an Information Service to find available WFS. Apart from discovery of the services, WMS can create capabilities file of a WFS on the fly, as the IS provide extensive information about the capabilities of WFS. An IS provides consistent and uniform API for publishing and discovering OpenGIS Web Services, and it is defined by a WSDL. Once the WFS are dynamically discovered through IS, WMS can then invoke corresponding WFS to retrieve the features that it needs.

3.5 Visualization Service - WMS

WMS is the key service to the GIS visualization system. WMS produce maps from the geographic data. A map is not the data itself. Maps create information from raw geographic data, vector or coverage data. Maps are generally rendered in pictorial formats such as jpeg (Joint Photographic Expert Group), GIF (Graphics Interchange Format), PNG (Potable Network Graphics). WMS also produce maps from vector-based graphical elements in Scalable Vector Graphics (SVG) [20].

WMS provide three main services; these are getCapabilities (Section 3.5.1), getMap (Section 3.5.2) and GetFeatureInfo (Section 3.5.3). GetCapabilities and getMap are required services to produce a map but GetFeatureInfo is an optional service. These services and our implementations are explained in the following subsections.

3.5.1 GetCapabilities from WMS

Before a WMS Client requests a map from WMS, it should know what layers WMS provides in which bounding boxes. GetCapabilities request enables WMS Clients to obtain this type of information about the contacted WMS. GetCapabilities request allows the server to advertise its capabilities such as available layers, supported output projections, supported output formats and general service information. After getting this request, WMS returns an XML document with the metadata about the WMS Server. This capabilities file is kept in the local file system and sent to clients upon getCapabilities request.

After getting the request WMS parses it to derive parameters. If WMS verifies that the request, then it sends the capabilities file to the WMS Client as a SOAP attachment. If WMS encounters any problem during handling of the request than it sends exception message in SOAP back to the WMS Client. Basic getCapabilities request are pictured out at Figure 6.

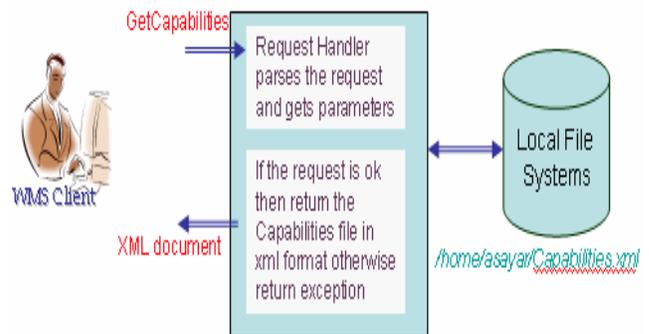


Figure 6 : getCapabilities work flow.

3.5.2 GetMap from WMS

Another service interface that WMS provides is GetMap request. The getMap service interface allows the retrieval of the map. Chained processes to produce maps are illustrated in Figure 7. This request is done by the client after finishing getCapabilities request and defining the available layers. After getting the getMap request, the WMS goes over the flow depicted in Figure 7 and if everything succeeds, then returns the result as an image in a format defined in the getMap request. All the supported image formats are defined in WMS Capabilities document. Requests for the image formats should be made in accordance with the WMS's Capabilities file. The image is returned back to the WMS Client as an attachment to SOAP message. If the WMS encounters any problem during handling of the request, it sends an exception message in SOAP back to the WMS Client.

WMS first parses the parameters and get their values from the getMap. Depending on these parameters, WMS might need to make some requests to some other WMS services. WMS first determines what layers are requested, in which bounding box, in which form, and so forth. After determining all the request parameters, it makes find_service and getAccess_point requests to IS to determine the WFS providing requested feature data. These requests are done as SOAP messages to IS service interfaces implemented as Web Services. GetAccess_point returns the Web Service access point address of the WFS that provides the requested feature. WMS makes getFeature request to the returned WFS and gets the requested feature data in GML format. If the parameter defining returned image format in getMap request is Scalable Vector Graphics (SVG), then WMS creates SVG from returned feature data by using its geometry elements. If the requested image is not in SVG format, we first create the SVG image and then convert it into the desired image formats (such as PNG, GIF, or JPEG). Apache Batik provides libraries for this conversion. Batik is a Java(tm) technology based toolkit for applications or applets that use images in the SVG format for various purposes, such as viewing, generation or manipulation. Schema files for the geometry elements are well defined. By using these schema files we derive geometry elements from the GML file to visualize the feature data. These geometry elements in GML [9] are basically Point, Polygon, LineString, LinearRing, MultiPoint, MultiPolygon, MultiGeometry, etc.

To create the images from the features returned from the WFS, we have used Java Graphics2D and Java AWT libraries. For the each

layer we create a different graphics object. If you assign each layer to different graphics object than Java libraries allow you to overlay these graphic objects.

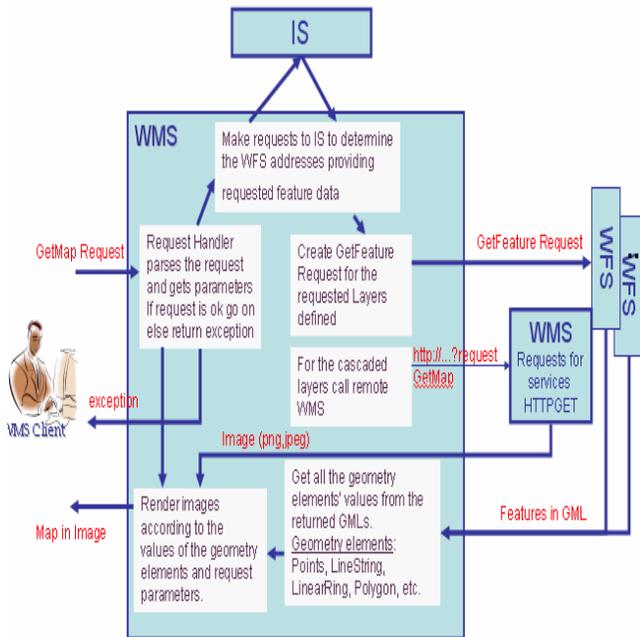


Figure 7 : getMap work flow.

3.5.3 GetFetureInfo from WMS

This is an optional WMS service. It is not necessary to create a map. It is used only when a user needs further information about any feature type on the map. However, we have found this very useful when building interactive user interfaces to geophysical applications. The GetFeatureInfo method allows us to send additional information (such as earthquake fault dimensions and material properties) to simulation codes that use these as inputs [10, 11].

The GetFeatureInfo works as follows: the user supplies an (x, y) Cartesian coordinate and the layers of interest and gets the information back in the form of HTML, GML or ASCII format. All these supported formats are defined again in WMS Capabilities file. Figure 8 illustrates the successive processes done by the WMS to respond to getFeatureInfo requests from the WMS Client. To make the presentation more concrete in the figure, we assumed the feature information is requested in text/HTML format. This value is defined in parameter “info_format” in getFeatureInfo request. GetFeatureInfo service interface supports two more info_formats as well. These are plain text and GML formats. Since HTML creation requires a generic XSL [31] file and XSLT transformation, we have chosen this type of requests to demonstrate getFeatureInfo request processing in Figure 8.

All the processes explained in Section 3.5.2 for the getMap until getting requested features from WFS are same for the getFeatureInfo processing. Again all the remote invocations are done by using SOAP messages.

After getting the feature collections data from the WFS, instead of producing map as explained in Figure 7, WMS lists all the non-geometry elements and attributes in the returned GML file. For

the getMap request WMS deal with geometry elements of the returned GML file but for the getFeatureInfo WMS deal with non-geometry elements. From the list of non-geospatial elements, WMS creates a new XML file to be able to transform non-geometry elements into HTML. This XML file is simply another form of GML which includes just non-geometry elements, properties and attributes. To display all of the processes involved in getFeatureInfo handling (Figure 8), we assumed information is requested in HTML format. After creating new XML file from the non-geo elements, WMS creates HTML file from newly created XML file by using generic XSL file and XSLT transformation machine. For the detailed documentation about the getFeatureInfo, please see our project page [2].

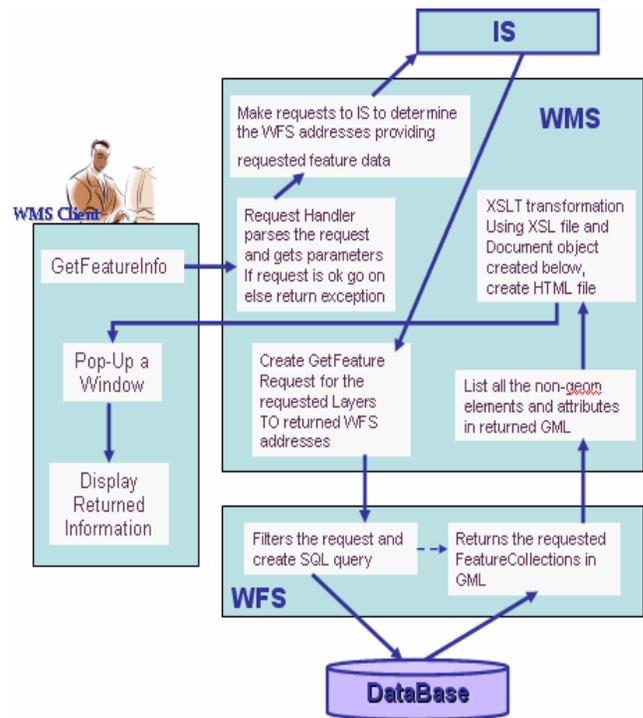


Figure 8 : getFeatureInfo work flow.

3.6 Bridging Web Service Oriented WMS to other WMS Instances

This section explains the architecture to combine Web Services based implementation of WMS systems with the third party WMS systems. Third party systems use HTTP as distributed computing platform.

Cascading WMS is the key issue to enable bridging of these two groups of visualization systems. A cascading WMS is a WMS which aggregates the contents of several individual WMS into one service that can be accessed by clients. Cascading WMS acts like a client to the other WMS and as a server to the clients [4]. The client does not need to keep track of several WMS servers; it only has to be aware of one. The client application does not need to know the ultimate source of all images.

A cascading map server reports the capabilities of other WMS as its own and aggregates the contents and capabilities of several

distinct WMS servers into one service. In most cases, the cascading map server can work on different WMS servers that cannot serve particular projections and formats themselves [5].

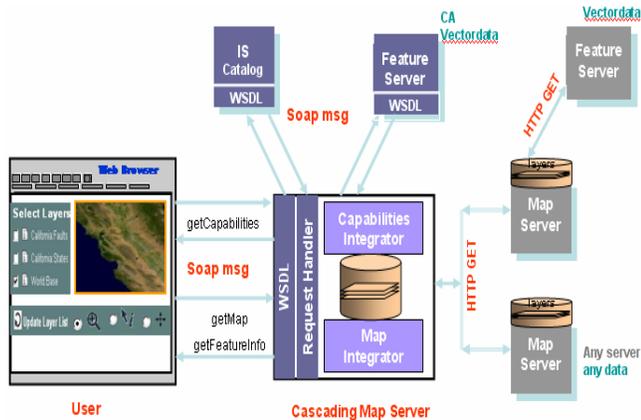


Figure 9 : Bridging of the Web Service-compatible WMS and other WMS.

Clients make their requests to cascaded WMS. Cascaded WMS services are implemented as Web Services. Clients create their requests and send them in SOAP messages over HTTP. WMS parse coming requests by request handlers. Request handlers derive all the parameters from the request and trigger the responsible modules in the WMS. Figure 9 gives a general depiction.

After getting and parsing the requests WMS defines the requested layers' names. WMS determines if the requested layers are cascaded or not by looking at its capability file. If layer is cascaded than WMS defines the other third party WMS providing requested layer by looking at the capabilities file. If the layer is not cascaded than WMS determines the addresses of the WFS services that provide these layers by making geo-query to IS. For the cascaded layers, requests to the other (non-Web Service) WMS instances are done over HTTP as defined in OGC specifications, HTTP GET and POST.

Figure 10 illustrates this. We have combined earthquake fault and state-boundaries data as features from a WFS server with Landsat 7 satellite imagery map from WMS at NASA OnEarth [29]. WMS from OnEarth provides access to the World map via OGC compatible HTTP GET and POST requests. We are using these clients to set up geophysical simulation runs, as initially described in [11, 12]

3.7 WMS Client

We also have been implementing a portlet-based browse client to our Web Service based standard visualization system for testing and the demonstration purposes. A sample WMS client is shown in Figure 10. Several capabilities are implemented for the user to access and display geospatial data. Our WMS client enables the user to zoom in, zoom out, measure distance between two points on the map for different coordinate reference systems, to get further information by making getFeatureInfo requests for the attributes of the features on the map, and drag and drop the map to display different bounding boxes. Users can also request maps for the area of interest by selecting predefined options clicking the drop-down list. The user interface also allows the user to change

the map sizes from the drop-down lists or enable them to give specific dimensions. Zoom-in and zoom-out features let the user change the bounding box values to display the map in more or less details. Each time user change the bounding box values, user interface shows the updated bounding box values at the each side of the map.

We have developed WMS Client shown in Figure 10, by using Java Server Pages (JSP), Cascading Style Sheets (CSS) and Java Script technologies. We have also developed a portlet version of the WMS Client to be able to deploy in a JSR 168-compatible portlet container. This simplifies distribution of our client application.

WMS services are stateless services. Each time a user makes a request, the WMS client creates a new request object and invokes remote WMS. All the requests are created according to schema files defined in Section 3.3 and wrapped into the SOAP envelope. After creating SOAP message it is sent over HTTP to the remote WMS. Invocation is done by the WMS Client-stubs created by using Apache Axis 1.2 [30].

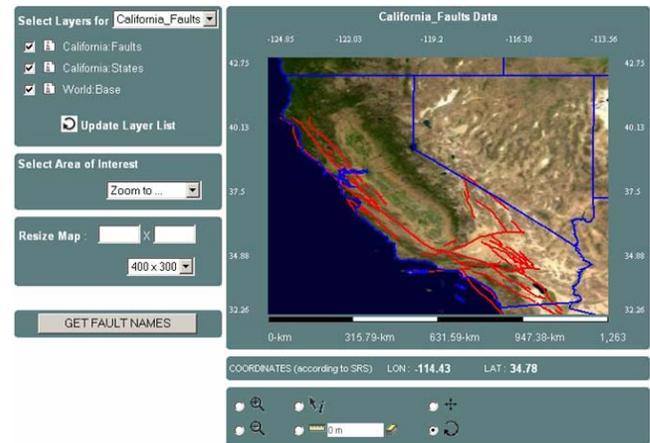


Figure 10: Project Demo page with the geophysics application. It uses California Fault data and state-boundaries data.

We are currently interesting in upgrading the client and WMS server to provide scientific visualizations, real time streaming, and collaborative mappings. For the detailed future works please see the Section 4.

4. FUTURE WORK

The first goal in the near future is improving the quality of maps. To do this, we are planning to implement Web Coverage Service (WCS) [13], Coverage Portrayal Service (CPS) [24] and Styled Layer Descriptor (SLD) Service. All these services have corresponding OGC specifications and they should be implemented according to the specifications to become OGC compatible. All should have well defined service interface described in their WSDL files. Each of these services can be implemented as a standalone application, but we will be deploying them in our project step by step. First we will finish implementation

according to specifications and then handle the interoperability issues between these and already used OGC services.

Performance is a key issue. To improve performance we need to handle common problems in the GIS. We are planning to make a contribution to solution by generating new algorithms, generating new optimization techniques, using distributed rendering and tiling, parallel rendering of images etc.

We plan to use our WMS services for scientific visualization. To be able to adapt WMS to scientific visualization we need to handle high volume of data. This requires us to solve performance problems by motivating distributed High Performance Computing and collaborative shared WMS supporting multiple simultaneous Clients.

We will be working on optimization and performance algorithms of the system. To accomplish this, we will need to handle image pipelining, faster rendering, caching or client rendering.

5. CONCLUSION

With the development of spatial information application and the network technique, the spatial data between different districts and different departments need to be shared and to be made interoperable. ISO/TC211 and OGC have defined interface specifications and standards to ensure sharing and interoperable capability of the spatial data. By adapting these to Web Service standards, we simplify the interoperation of GIS services with other service domains.

In this document we have described our efforts to build an OGC compatible GIS Services by using Web Service technologies and OGC specifications.

We can extend OGC OpenGIS specifications as much as we can, but we need to consider the performance issue. This will be an important issue for us in upcoming work. Since images can be too large, capabilities documents can be too large and transferring these data over the internet is cumbersome, our first priority will be researching techniques for improving WMS performance. Visualization can be slow as overlays or even basic maps become large. Complicated maps also require large capabilities files, and parsing these can be a bottleneck. Such efficiency and performance issues will be important also to our investigations of streaming map servers.

6. ACKNOWLEDGEMENTS

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