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OGC Catalog Services: a key element for the development of Spatial Data Infrastructures

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Abstract

One of the essential components for the construction of a geographic spatial data infrastructure at a regional, national or global level is the geographic information catalog server. But, for the catalog to be a useful component, it must enable access to geographic information metadata independently of the nature of search client applications, in other words, client applications do not need to be developed by the same company or same technology that implemented the server. In this sense, the contribution of the OpenGIS Consortium, an organization which promotes the standardization mechanisms for catalog services, is to provide the tool that makes possible this enterprise and technological independence. The objective of this paper is to review current approaches, provide some inside on the software implementation of catalogs, and show the applicability of these catalogs in real world scenarios.
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1. Introduction

Geographic information (also known as geospatial data) describes phenomena associated directly or indirectly with a location with respect to the Earth surface. This information is vital for decision-making and resource management in diverse areas (natural resources, facilities, cadastres, economy, etc.), and at different levels (local, regional, national or even global) (Buehler and McKee, 1996). Nowadays, large amounts of geographic data are gathered by different institutions and companies. In fact, it is recognized that around 80% of the database used by the public administration contain some kind of geographic reference (postal codes, cartographic coordinates, etc.). Furthermore, the volume of this information grows day by day thanks to important technology advances in high-resolution satellite remote sensors, Global Positioning Systems (GPS), databases and geo-processing software notwithstanding an increasing interest by individuals and institutions. Even more, it is possible to georeference complex collections of a broad range of resource types, including textual and graphic documents, digital geospatial map and imagery data, real-time acquired observations, legacy databases of tabular historical records, multimedia components such as audio and video, and scientific algorithms.

In recent years nations have made unprecedented investments in both information and the means to assemble, store, process, analyze, and disseminate it.

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Thousands of organizations and agencies (all levels of government, the private and non-profit sectors, and academia) throughout the world spend billions of euros each year producing and using geographic data (Somers, 1997; Groot and McLaughlin, 2000). This has been particularly enhanced by the rapid advancement in spatial data capture technologies, which has made the capture of digital spatial data a relatively quick and easy process. Additionally, it is also worthwhile mentioning the impact of the Internet in the distribution of geographic information resources. As well as other information resources, lots of geographic information resources are also available on the Internet.

However, almost every new project or study implying the use of geographic information requires the creation of new geographic information resources from scratch. This apparent lack of reusable resources may be motivated by the following circumstances: (a) most organizations need more data than they can afford; (b) some organizations, despite being public institutions, are reticent to distribute high-quality information; (c) data collected by different organizations are often incompatible; (d) in most cases, there is a lack of knowledge about what data is currently available; (e) the increasing complexity of discovery and information retrieval services. In conclusion, despite the potential uses of geographic information and the important investments in their creation, nowadays geographic information is not exploited enough. Several studies (Craglia et al., 1999; Official Journal of the European Union, 2003) have remarked that although the value of geospatial data is recognized by both government and society, the effective use of geospatial data is inhibited by poor knowledge of the existence of data, poorly documented information about the data sets, and data inconsistencies. It is said that "information is power", but with increasing amounts of data being created and stored (but often not well organized) there is a real need to document the data for future use—to be as accessible as possible to as wide a "public" as possible. Data plus the context for its use (documentation) become information. Data without context are not as valuable as documented data. This necessity is of the utmost importance in the case of geographic information. Once created, geospatial data can be used by multiple software systems for different purposes. Over 35 years ago, humans landed on the Moon. And data from that era are still being used today, and it is reasonable to assume that today's geospatial data could still be used in the year 2020 and beyond to study climate change, ecosystems, and other natural processes.

As it can be deduced, there is a need for creating networked solutions to facilitate the discovery, evaluation and access of geographic data. Spatial Data Infrastructures (SDI) provide the framework for the optimization of the creation, maintenance and distribution of geographic information at different organization levels (e.g., regional, national, or global level) and involving both public and private institutions (Nebert, 2001). The main goal of this kind of infrastructures is to facilitate and enable an efficient exploitation of geographic information by the multiple stakeholders in the geographic information market. And one of the main components of an SDI is a geographic catalog that enables users, or application software, to find the information that already exists within a distributed computing environment.

According to (Kottman, 1999) geographic catalogs are a solution to publish descriptions of geospatial data and enable searches across multiple servers. These descriptions of geospatial data are called metadata ("data about data") and their content structure is established by recognized organizations (FGDC, 1998; ISO, 2003). The use of indexed and searchable metadata provides a selected and disciplined vocabulary against which intelligent geospatial queries can be performed, thus enabling the understanding among users from the same or different geographic information communities.

Another feature that must be taken into account is that it does not seem reasonable to think about the development of different catalogs that work like standalone nodes and are accessed only by client applications developed by the same company or with the same technology. On the contrary, in order to promote the sharing of geographic information throughout the maximum number of users, it is necessary to create distributed networks of catalogs that use a standardized mechanism for catalog querying, thus enabling enterprise and technological independence. A successful example of such a network is the National Geospatial Data Clearinghouse project,[1] which was developed by the Federal Geographic Data Committee (FGDC) as a key component of the US National Spatial Data Infrastructure. The nodes of this network conform to the ANSI/NISO Z39.50 information and retrieval protocol (ANSI, 1995), which has been widely used since the beginning of the 1990s for the construction of Online Public Access Catalogs (OPACs). And although the Clearinghouse project had originally a national character, many servers from other countries (e.g., Canada, Australia, South Africa or Uruguay) have adhered to the initiative. A more recent initiative for the standardization of catalog services is the one proposed by the OpenGIS Consortium (OGC).[2] OGC is an international industry consortium of more than 230 companies, government agencies, and universities aimed at growing

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[1]Homepage of the National Geospatial Data Clearinghouse: http://www.fgdc.gov/clearinghouse/clearinghouse.html (last access: April 2004).

[2]Homepage of the OGC: http://www.opengis.org (last access: April 2004).

interoperability for technologies involving spatial information and location. Its mission is to promote the development and use of advanced open systems standards and techniques in the area of geo-processing and related information technologies delivering spatial interface specifications that are openly available for global use. And one of these specifications is the OpenGIS Catalog Interface Implementation Specification (Nebert, 2002). This specification does not provide enhanced capabilities, in comparison with the Clearinghouse that uses the Z39.50 protocol (one of OGC profiles is even compatible with Z39.50), but from a broader perspective, this specification can be more useful because it has been conceived as a part of an integrated and interoperable architecture of geographic information services. Fig. 1 illustrates a typical use of the catalog service. The figure corresponds to a web catalog client currently used in the first version of the Spanish Spatial Data Infrastructure, which is being used to search spatial data in several catalogs located at the Spanish National Geographic Institute, the Catalonian Spatial Data Infrastructure and other institutions. These catalogs offer access through standardized OGC interfaces.

The objective of this paper is to illustrate the benefits of using standard catalogs in the development of spatial data infrastructures, and how they can be used for building other kind of specific services. Additionally, it is shown the main aspects arisen in the development of a geographic information catalog that complies with the WWW profile of the OpenGIS Catalog Interface Implementation Specification (version 1.1.1). The rest of this paper is structured as follows. Section 2 introduces the OGC specifications. Section 3 presents a use case developed over the use of standardized catalogs. Section 4 shows the work done for the development of an OGC standard catalog. And finally, this paper ends with some conclusions.

2. Introduction to the OGC specification and its available implementations

Geospatial data and services catalogs allow people and software clients and services to find out which data repositories or services are available and appropriate for their use. The OpenGIS Catalog Services Specification (Nebert, 2002) explains how the Catalog Services are organized and implemented for the discovery and retrieval of metadata that describes spatial data and geoprocessing services. The introduction states: "*Catalog services support the ability to publish and search collections of descriptive information* (*metadata*) *for data, services, and related information objects. Metadata in catalogs represent resource characteristics that can be queried and presented for evaluation and further processing by both humans and software. Catalog services are required to support the discovery of registered information resources within a collaborating community.*"
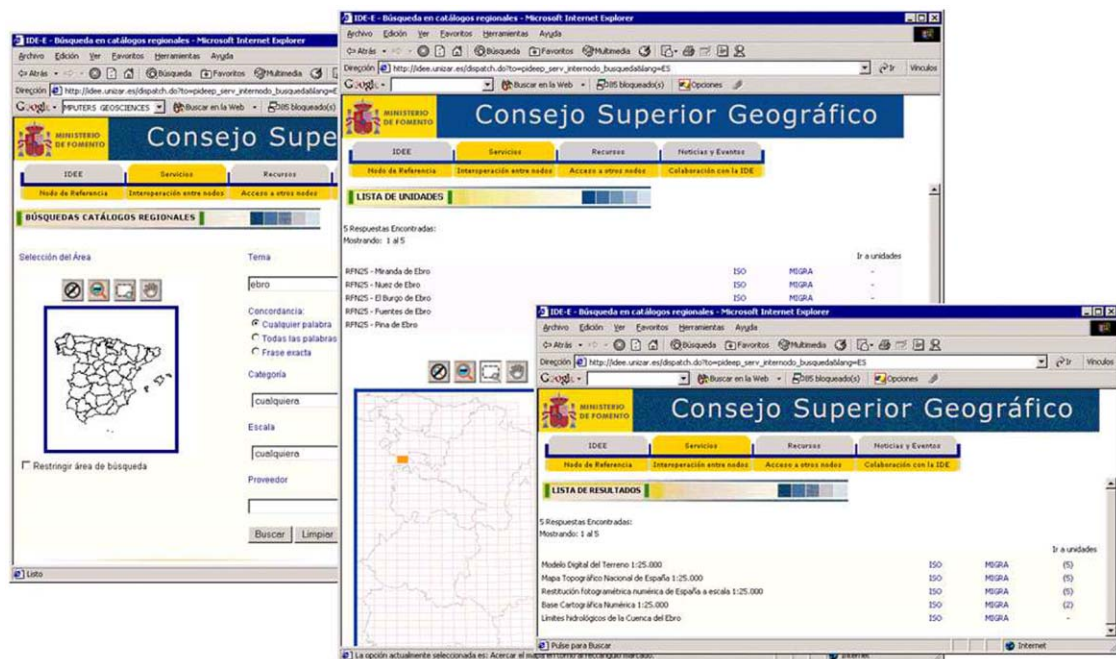

Fig. 1. Example of a web catalog client in Spanish (SDI).

OGC members have reached the consensus that catalogs based on the OpenGIS Catalog Services Specification should have the following characteristics:

- The specification defines services to enable "automated discovery of", "automated access to" and "management" of machine-readable metadata describing data that are held in online repositories (and perhaps offline data repositories) and also metadata describing online OGC and related Web Services. OGC Web Services are geoprocessing Web Services accessible through interfaces that implement OpenGIS Specifications. The OpenGIS Catalog Services Specification guides incremental expansion from simple manual spatial data clearinghouses to catalogs that enable fully automated searches for both data and services.
- Catalogs and OGC Web Services are based on the IT industry's emerging Web infrastructure for "publish, find, bind". This infrastructure establishes standard ways of: encoding and publishing metadata that describe online services; finding those resources via their metadata; and binding (making the programmatic connection between) service requests and services, including chaining of multiple services from different sources.
- The specification provides different profiles of the catalog services interface according to the distributed computing platform where they are going to be implemented. In particular, within this specification the profiles for CORBA (Orfali et al., 1999), WWW (compatible with the search and retrieval protocol Z39.50) and OLEDB/COM (Gordon, 2000) are provided.
- The metadata (for both data and services) registered in catalogs must adhere to certain (ISO/OGC) metadata schema standards. Other metadata schema standards and data content standards are not mandatory but may also be useful for certain information community users.
- Whichever schemas are employed to structure the metadata, all metadata involved with Web Services are encoded using the eXtensible Markup Language (XML) (Bray et al., 2000).
- The content metadata provides information about how to access (view, retrieve, manipulate) the geospatial data. This data can be in any raster or vector data format (or even text or video), and they can be held in any data server. However, the data server will not be able to respond automatically to access requests unless the system is online and fitted with interfaces enabling client/server communication. Typically, these will be interoperability interfaces that conform to OpenGIS Specifications.

Through the OGC Web site it is possible to browse a list of the products conformant to the OpenGIS Catalog

specification.[3] However, despite the initial relevance of catalog interface specifications, the implementations are not many in comparison with other OGC specifications. This might be explained by the initial OGC development policy which gave top priority to testbeds and pilot projects for the establishment of basic Web Mapping specifications (Beaujardière, 2002). Additionally, most of the registered products are integrated within bigger Web Services infrastructures, so there is a clear tendency for implementing Web interfaces instead of complex CORBA or COM distributed architectures. Currently, OGC is going to release the new version of the OpenGIS Catalog Services Specification (Nebert, 2004). Maybe the most relevant features this version presents are: the explicit mention of the Filter Encoding Specification (Vretanos, 2001) as a valid XML implementation of the OGC Common Query Language; and the design of the Web profile more oriented to the Web Services architecture (Booth et al., 2004; Graham et al., 2002), which proposes the use of underlying web technologies such as Simple Object Access Protocol (SOAP) for Remote Procedure Call (RPC) communication between clients and servers, Web Services Description Language (WSDL) to describe service capabilities, or Universal Discovery, Description and Integration (UDDI) as the standard for service registries.

3. Integrating catalogs with real world applications

This section presents a use case of a public administration which has developed a spatial data infrastructure over a standard catalog and how it has improved the quality and effectiveness of its operative work. The context of this example is the Ebro River Basin Authority (CHE). This Spanish authority is responsible for the physical and administrative management of the hydrographical basin of the Ebro River, through planning (by elaborating and revising a global catchment hydrological plan), managing (by administering and controlling the different water resources in the catchment area) and investing (by projecting and carrying out the public works that may be entrusted to them).

Water points, i.e., water resources like wells, springs, drains or reservoir collectings, are one of the areas of interest inside the CHE Hydrological Planning Department, whose administrative work is mainly devoted to analyzing and approving water point exploitation by particulars. Given a water point concession request, the workflow process accomplished by this department includes: the gathering of data relative to the water

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[3] Registered Products Implementing the OpenGIS Catalog Interface 1.0. Accessible at: http://www.opengis.org/resources/ ?page = products (last access: April 2004).

point, including nature, location, exploitation and administrative status; the analysis of the collected data, by comparing it with data about other points, the exploitation data given by the stakeholder and the river basin management plan objectives; the delivering of several reports about the physic characteristics and location of the point; and a final resolution about its compatibility with the river basin management plan, allowing or denying the exploitation of the point.

As it can be supposed, this workflow process needs large amounts of data, most of them georeferenced, that must be collected and organized in a structured way. Indeed, the data involved in this process, which are compiled as the Water Point Inventory (IPA), can be considered as the most relevant set of data created and maintained by the CHE due to its key role in the organization and to its volume (more than 50,000 water points inventoried so far). This inventory includes water points data, administrative dossier information, superficial and groundwater quality status and hydrogeology. Additionally, it must be taken into account that apart from what is directly involved in the organization workflow, which is CHE's property and responsibility (CHE is in charge of collection and maintenance), it is also necessary to use other geographic data as support for the daily work. Examples of this support data are cartographic data series obtained from the Spanish Geographic National Institute (IGN)

or the administrative land divisions from the Spanish Cadastre Office.

Not many years ago this inventory consisted uniquely of a central repository of these datasets (and their corresponding metadata) without any automated process for its administration. The creation (or modification) of data related to water point concessions had to be performed offline and the central repository was only synchronized once or twice a year. This way of working created frequent problems that were due to the work with out-of-date data. Therefore, in order to overcome this type of problems, the CHE launched a project for the automation of the creation, maintenance and access of all its geographic resources, considering this inventory as one of its main goals. As a result of this project, the CHE has developed its own spatial data infrastructure (Latre et al., 2003), which gives public access to the data owned by the CHE. And making use of the services offered by this SDI it has built an information system perfectly adjusted to the necessities of the inventory. Furthermore, the next version of this SDI-based information system will have the ability of accessing the data supplied by other providers (e.g., the IGN or the Spanish Cadastre Office), which are accessible through their spatial data infrastructures thanks to the use of OGC standard interfaces.

As it can be observed in Fig. 2, the water point inventory tool locates the information it needs by
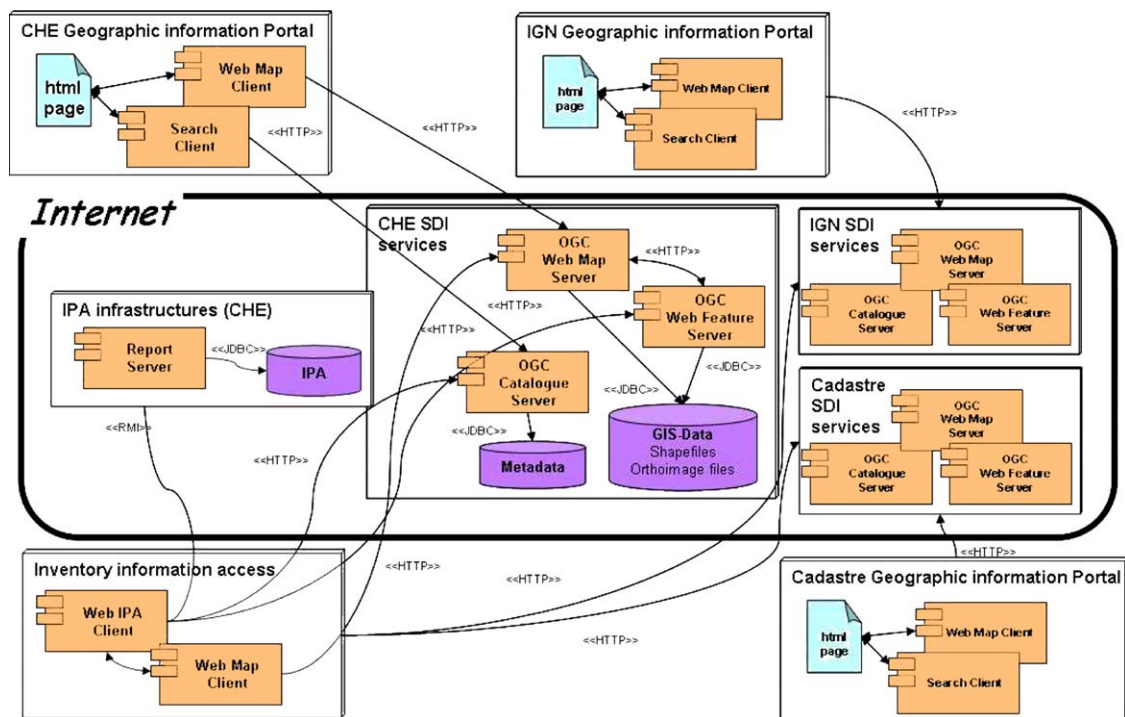

Fig. 2. Water point inventory architecture.

searching (through the Inventory Information Access component) in the OGC catalogs provided by different spatial data infrastructures. Because all the infrastructures implement the OGC catalog interface, the operation with all of them is identical. Once the necessary resources have been found, the tool can access other services of the infrastructure to retrieve the data and incorporate them with the IPA creation and maintenance process. Additionally, the tool includes an independent server that enables the construction of the administrative and informative reports requested by the users. The main reason to provide this server is to avoid the increase of workload in the client computers. Furthermore, the report requests are also launched as background processes in the server and when the report files are completed, they are placed in an accessible directory inside the organization. The client receives the document URL and can open it with its default application viewer. Reports are divided into different categories depending on the nature of their structure and the generated file format. For instance, it is possible to generate static reports with a predefined structure in Word, Excel, ArcView or Acrobat PDF formats. This kind of reports are filled using queries with default parameters and they may include: comprehensive data stored about a single point or a set of them in PDF format; basic data and piezohydrometry series of a set of points in Excel format; and hydrochemical Piper and Stiff graphics in ArcView. Other possible reports are the dynamic reports, which are based on templates not completely fixed. The final structure of these reports is determined at run-time and it depends on the specific content that will appear. For example, the administrative resolution reports, which are delivered in Word format, combine data coming from one or more water points and these data are organized in a certain structure of sections and paragraphs depending on the nature of the point. The structure and content of these sections and paragraphs are stored in the database, so it can be maintained and updated along time.

4. Building a standard catalog

This section presents the work done by an R&D group from the University of Zaragoza (Spain) to build a standard catalog in compliance with the WWW profile of the OpenGIS Catalog Services (version 1.1.1). This catalog is being used in several projects for the development of different SDI initiatives in Spain and at different levels (national, regional and local).

4.1. Assumptions and restrictions in our implementation

The WWW profile proposed by OGC is based on a message-passing client/server architecture. The profile establishes a mapping between each one of the operations belonging to the catalog interface general model and the corresponding service specified by the norm ANSI/NISO Z39.50 (ANSI, 1995), also gathered at international level as ISO 23950. Besides this the WWW profile specifies the use of one of the following transport mechanisms:

- Directly over TCP where the services are encoded using the Basic Encoding Rules (BER) (ISO, 1990). This option is in fact the direct adoption of the Z39.50 standard, which according to BER rules encodes the protocol messages (specified in Abstract Syntax Notation ASN.1) as binary octets.
- By means of the Hyper Text Transport Protocol (HTTP) where the services are encoded using XML Encoding Rules (XER).[4] XER are encoding rules analogous to BER that translate this protocol messages into XML.

The implementation presented in this work has chosen the second of the transport mechanisms. The client sends request messages to the server, which in turn responds to them over HTTP. Within the interface for this implementation, each operation corresponds to a Z39.50 service, each service consisting of a client request message and the pertinent server response message.

During the development process, some problems and weaknesses have been identified in the version 1.1.1 of the OGC specification, and they have implied the adoption of some decisions and assumptions. The more important ones are detailed next:

- Selection of the query language. The query languages (for specifying restrictions) that appear in the OGC specification are the OGC Common Query Language (similar to the specification of WHERE clauses in SQL) and RPN languages (Z39.50 protocol languages to specify restrictions), but this specification does not exclude other languages (the specification in XML of the restriction within a *SearchRequest* message is flexible and allows this). In fact in the latest OpenGIS specifications, e.g., Web Feature Server (Vretanos, 2002) or Web Services Stateless Catalog (Reich and Vretanos, 2001), the generalized form to express restrictions is by means of a specification denominated Filter Encoding Specification (Vretanos, 2001), which is based on the XML language. Moreover thanks to the advances in technologies and tools available for the treatment of XML, this language is much more suitable for the catalog implementation or for the creation of user interfaces that facilitate the construction of restrictions. Therefore, given its widespread

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[4]XML Encoding Rules (XER). Available at http://asf.gils.net/xer (last access: April 2004).

use and additional facilities, this last query language has been selected.

- Some optional services have not been implemented. There are some messages for service-requirement that are specified in the optional part of the OGC interface, so they do not correspond to any mandatory message. The most important reason to justify this omission is that they are not offered in later OGC specifications with analogous objectives. This is the case of the Web Services Stateless Catalog (Reich and Vretanos, 2001) which differs from a geographic information catalog in that a services catalog manages metadata describing services, while the second one manages metadata describing geographic resources. This implementation provides a default treatment of these services, but the response messages given to an OGC client indicate that the service is not supported. This allows the server to be complete and consistent under any circumstance.

4.2. Design of the catalog

The implementation of the OGC standard interface has been based on the use of a geographic information catalog component, denominated *CatServer*, that had been previously developed by the authors of this paper. For the development of this component, the functionality offered by the different OGC interface profiles (especially the CORBA profile) was taken into account. *CatServer* is a Java component accessible via Java-RMI

that is able to manage user sessions. The services offered by this component correspond to those of the interface in charge of administration and discovery (search and presentation) of metadata. Besides this, this server offers additional services for the management of this catalog such as user control, license control, statistics of use and so on. More details about this component can be found in (Zarazaga et al., 2000).

Two main elements can be distinguished in the design of the OGC catalog: the design of the server and the design of the messages that will be exchanged between client and server. Fig. 3 shows a UML class diagram with the basic classes that integrate the server. The *OGCServer* class is the class that provides the HTTP interface, i.e., it processes the Protocol Data Units (PDUs) of the HTTP protocol. Since it inherits from the Java *HttpServlet* class, it is implemented as a typical Java servlet, and thus it makes profit of the Java infrastructure to establish HTTP socket connections between clients and servers. Additionally this class invokes the *SessionsCatServerRequestProcessor* class that, by means of the *processRequest* method, takes care of all the requests, identifying them and invoking the appropriate private method of type *processRequest*, which corresponds to the processing required. These private methods are those that call the suitable services of the *CatServer* component and create the response messages.

For instance, Fig. 4 shows the sequence of calls that are performed to attend a typical request: a request for
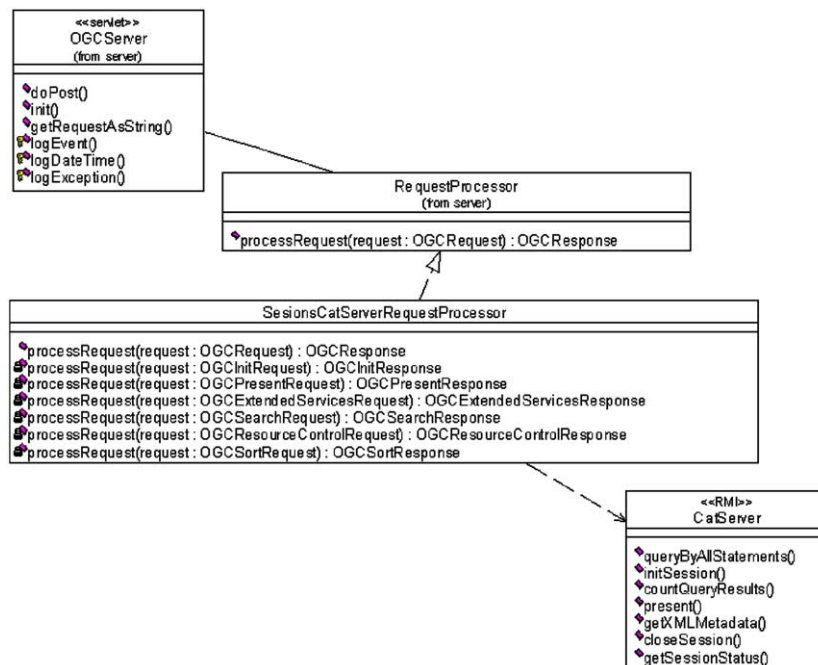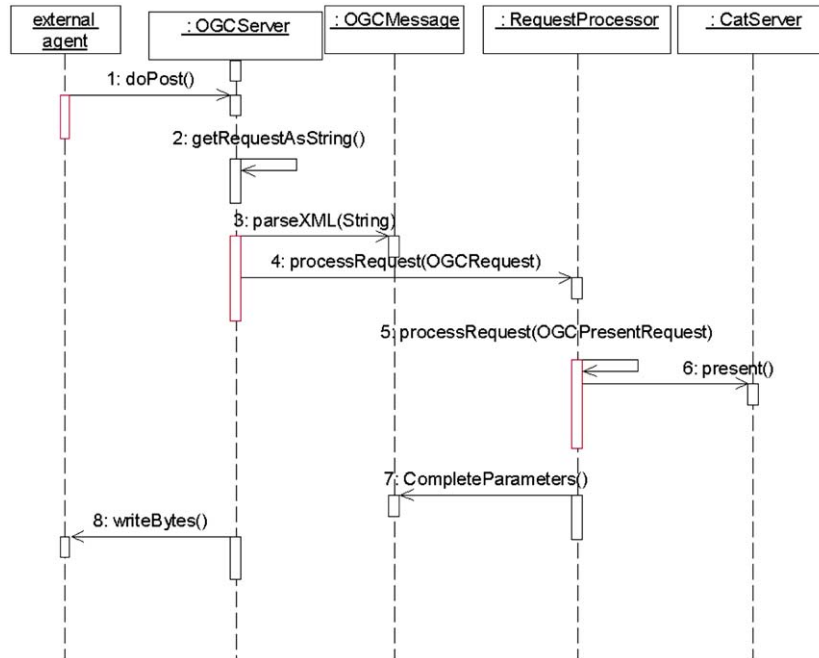

Fig. 3. Design of OGC catalog server.

Fig. 4. Sequence of calls to attend a request.

the presentation of results that corresponds to a previous search request. When a client makes the request, the *doPost* method of the servlet obtains the request as a String and translates it into an *OGCRequest* object. Then the generic *processRequest* method of the *SessionsCatServerRequestProcessor* class is invoked. And depending on the type of request, it calls the corresponding private *processRequest* method. In this example where the client has requested a presentation of results, it would invoke the *processRequest(OGCPresent-Request)* method. The task of these private methods is to select and request the appropriate service of the *CatServer* component that will finally retrieve the metadata records requested by the user, the *present* service in this case. And once the *CatServer* has done its job, the *processRequest* method will verify that every-thing has been successful in *CatServer*, will complete the response message for the client, and will return this message to the *OGCServer* servlet, which in last instance will deliver it to the client.

The aforementioned communication mechanism is based on the exchange of messages that are encoded in XML according to the standard interface specification. The management of these messages is made through the hierarchy of classes that appears in Fig. 5. The *OGCMessage* class is the base class of this hierarchy and it gathers all the methods and common attributes to all the messages, both requests and responses. Then, this class is specialized into the derived classes *OGCRequest* and *OGCResponse*, which are used to define the

common features of request messages and response messages, respectively. And similarly, those classes are, in turn, the base classes of a next level of derived classes that finally correspond to the specific requests and responses of each service in the specification. For instance, Fig. 5 shows the classes representing the messages concerned with the *Init* and *Search* services. For the sake of clarity, the rest of classes in the hierarchy have not been displayed.

Finally, it must be mentioned that this catalog implementation gives full support for the messages corresponding to the mandatory OGC services *Init*, *Search*, *Present*, *ResourceControl*, and *Close*. That is to say, it is able to understand the client request messages and returns coherent and non-empty responses to these requests. And for the rest of optional services, *Sort* and *ExtendedServices*, this catalog returns, at least, default messages indicating that the service is not supported for the moment. As it was mentioned in section 4.1, other OGC proposed specifications with comparable objec-tives do not include these latter services.

4.3. Deploying the catalog on the Web

At present, there is an operative version of this OGC-compatible catalog implementation that has been installed on a Web server hosted by the University of Zaragoza (see Fig. 6). This version works against the same instance of the catalog server (*CatServer*) that is usually accessed by other researchers for development
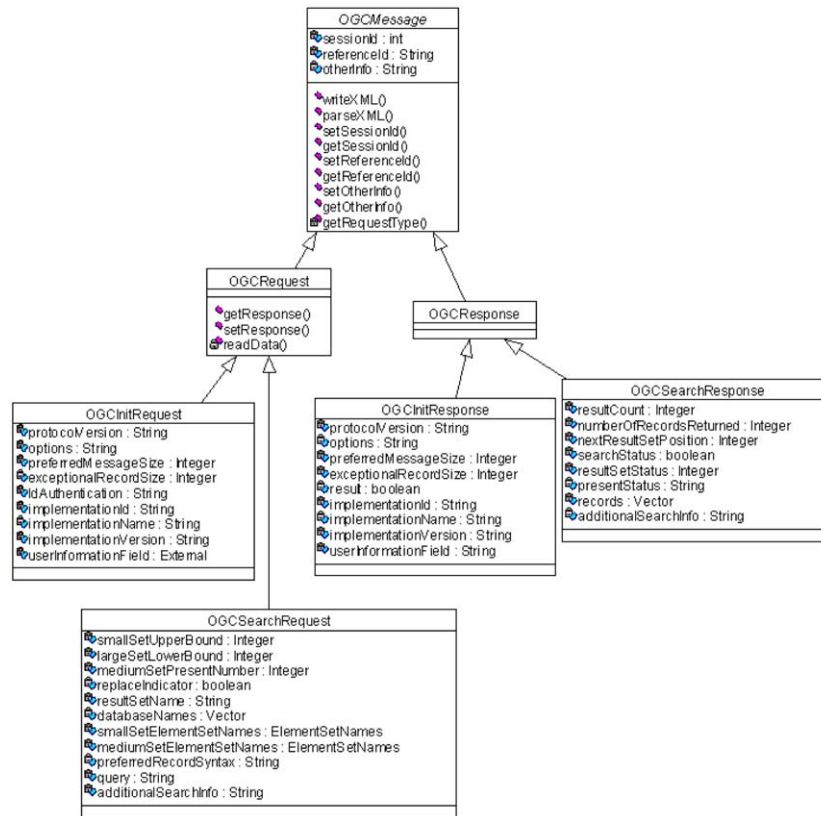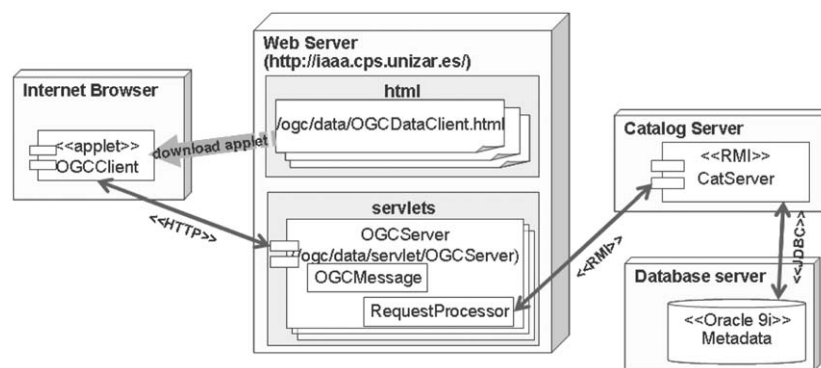
Fig. 5. Hierarchy of messages.

Fig. 6. Deployment of OGC catalog.

and technological demonstration purposes. Additionally, this version allows the selection of the metadata standard that will be used to specify the property names in search requests (*Search* service) and to receive metadata records (*Present* service). Currently, it is possible to choose between the American standard CSDGM (FGDC, 1998) and the international standard ISO 19115 for geographic metadata (ISO, 2003).

Through the URL http://iaaa.cps.unizar.es/ogc/data/OGCDataClient.html, a catalog client, implemented as a Java applet, can be downloaded to perform queries against this catalog server (the URL of the server is http://iaaa.cps.unizar.es/ogc/data/servlet/OGCServer). This client offers a simple graphical user interface whose main objective is to validate the correct implementation and operation of catalog services. It does not aim at
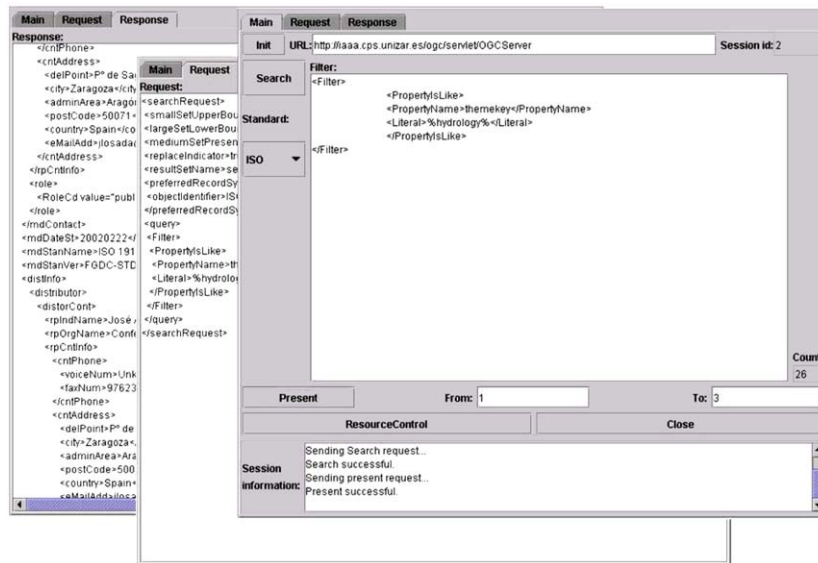
Fig. 7. Applet client giving access to OGCServer.

offering an ergonomic interface; it just serves as technological demonstration (see Fig. 7).

5. Conclusions

This work has presented how the use of standard catalogs can help for building spatial data infrastructures, and how they can be used for building other kind of specific services. It has been illustrated by a use case of a public administration which has developed a spatial data infrastructure over a standard catalog.

Additionally, this work includes the main aspects arisen in the development of a geographic information catalog compatible with the WWW profile of the OpenGIS specification. This development has been implemented in Java and has made use of a catalog server component that had been already developed by the authors of this paper. This work complements this previously developed component since this OGC interface enables the instantiation of interoperable geographic information catalogs within distributed networks where each catalog node complies with the same interface, but whose implementation do not need to be based on the same technology. Given the frequent technological dependence derived from the election of a particular product or technology, this development based on standard interfaces results crucial to avoid problems of interoperation.

Finally, it must be remarked that the new tendency of OGC with respect to catalog specifications is to unify data catalogs and service catalogs. The OGC refers to these catalogs as "geospatial catalogs" because they describe or refer to geospatial content and/or services. According to recent OGC publications (Nebert, 2004), a geographic data catalog can also be extended to store and maintain service metadata. Furthermore, it is believed that future versions of the OpenGIS Catalog Services Specification will establish a methodology for "stateless" catalog transactions following a true Web Services architecture (Booth et al., 2004; Graham et al., 2002). Until 2002, the OGC strategy was to design ad hoc HTTP message-passing protocols. But nowadays, OGC (Lieberman, 2003) suggests that new versions of OGC services should comply with the Web Services architecture using underlying web technologies such as Simple Object Access Protocol (SOAP) for Remote Procedure Call (RPC) communication between client and servers; Web Services Description Language (WSDL) to describe service capabilities; or Universal Discovery, Description and Integration (UDDI) as the standard for service registries.

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