BROWSING SGML DOCUMENTS WITH MAPS : THE FRENCH "INVENTAIRE" EXPERIENCE

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ABSTRACT. For GIS, SGML document servers and other highly specialized application domains, the systems integration problem is essential since the available software often is complex and would be costly to reimplement or to modify. In this paper we describe a two-level architecture for integrating software components based on partial data integration and user interface synchronization. We also present a prototype implementation of this architecture.

1. INTRODUCTION

The growing facility to access distributed data via the World Wide Web has opened the horizon to new software environments integrating complex information from different application domains. Beyond this horizon, a big variety of data models and representations produced by sophisticated and highly-specialized software components have been discovered. Whereas the notion of URL (Uniform Resource Locator) facilitates the exchange of data by encapsulating various communication protocols, it does not solve the problem of data heterogeneity. This fact explains the growing interest and necessity in defining architectures and models for integrating related information from different application domains.

Real-world entities often share addresses or other geo-referencing attributes which might be exploited for the integration of data. For example, a document archive might store a collection of structured SGML (Standard Generalized Markup Language) [18] documents which describe historical buildings of the 18th century. The address of each building is contained in the document and corresponds to a point or a region on a map stored in a Geographic Information System (GIS). This spatial property might then be used in different ways starting from the simple graphical display on a map interface to complex query processing about the document contents and the positions of the buildings they describe.

Standard database technology supplies efficient storage and query processing of strongly typed complex objects and relations. But it also suffers from the lack of flexibility for storing and manipulating *complex, non-standard application specific data*. Examples of such data are structured documents (SGML, HTML, XML), computer-aided design (CAD) diagrams, spatial maps and images. A common solution to this problem is to extend the logical database model by some application specific Abstract Data Types (ADT) which are implemented by highly-specialized software components. These components allow query processing on both standard and application specific data and range from specific index structures to adapted user interfaces.

The ADT approach has several serious drawbacks. First, its implementation relies on a strict separation between the logical database model and the application specific abstract data types and leads to a *non-uniform processing* of "standard" and "non-standard" data. For example, recent research activities on constraint databases try to tackle this issue for

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spatial database applications by representing both kinds of data as generalized tuples in a constraint database system [15]. Second, whereas recent versions of commercially available Database Management Systems (DBMS) such as Oracle [17] or O_2 [14] provide extensions devoted to spatial data or other application specific information structures such as SGML documents [12], it still remains difficult to implement applications integrating for example SGML documents and spatial maps. The display and manipulation of complex data structures such as GIS maps, CAD diagrams or SGML documents generally need *adapted user interfaces*. Application specific data and software is *rapidly changing* with respect to new needs, architectures and algorithms. As it is the case for user interfaces, this is orthogonal to the development of standard application independent database software. A lot of complex data formats are proprietary and strongly integrated with *specific products*. This means that the format might change in any new version of the product and render existing database components obsolete.

Interoperability is the general term for describing issues concerning the cooperation of software in the joint execution of a task [22]. Building systems that combine resources and services in a distributed and heterogeneous environment raises a number of new issues concerning the exchange, modification (transaction management), integration (semantic interoperability) and querying of distributed data. All of these issues depend on the system's architecture which becomes a key issue for their implementation.

In this paper we describe the integration of two complex software components, i.e. an SGML document server and a GIS component. Our approach is based on the interoperation of these two components at the data level and the user interface level. Section 2 presents the French “Inventaire” (Inventory) project. The objective of this project is the digitalization of documents about the French patrimony which is managed by the French *Ministre de la Culture*. One of the main goals is to provide users with on-line access to documents through the Web. In Section 3 we describe the motivation for extending standard document querying and browsing with spatial functionalities. Section 4 presents a general architecture for integrating an SGML document server with a GIS component. The prototype implementation on top of a SGML document server based on the O_2 Object-Oriented DBMS and ESRI's commercially available product ArcView is presented in Section 5. Future perspectives based on a mediated approach are described in Section 6.

2. THE FRENCH ”INVENTAIRE” PROJECT

The ”Inventaire” (Inventory) project, realized by the French *Ministre de la Culture*, the *Institut National de Recherche en Informatique et Automatique* (INRIA), the *Conservatoire National des Arts et Mtiers* (CNAM) and the Euroclid company, aims the creation of structured documents on French historical monuments and the definition of access methods to this information through the Web. Currently, information about historical monuments is scattered. Textual descriptions, photos, sketches, maps are separately managed and only the paper form of the document puts all the elements together. The main goals of the project are (1) the definition of the SGML structure (DTD) and the representation of inventory documents, (2) the definition of the stages and the procedure for the creation of such documents (document workflow), (3) the creation of export interfaces to other formats (for existing national databases, for the consulting server, for CD-ROM distribution, etc.) , and (4) the support of an on-line access for consulting the documents through the Web. This paper presents one approach to the last issue.

Inventory data, organized in documents and folders, has a rather complex structure. Documents concern objects, buildings, aggregates of buildings and contain textual information, photos, plans, maps, etc. Folders may group documents on spatial (e.g. all monuments in Paris) or spatio-thematic criteria (e.g. all monuments of the 15th century in Paris). Several types of links may relate documents and folders : membership of documents to folders, inclusion of folders, relations among documents (e.g. a crucifix is located within a church, a cathedral has similar characteristics to another one).

An important property of monuments is their spatial location which is described by a geometric form (point, line, polygon) in the geographic space. Location plays a structuring role in the creation of inventory documents and folders, because spatial criteria are used to group elements and to build links between documents. Therefore, the geographic dimension is essential in browsing and querying documents. The user must be able to display maps, to navigate through the geographic space, to visualize monuments as spatial objects on the map, to express spatial queries on the location of monuments.

This paper focus on the integration of spatial clues for browsing and consulting of inventory documents through the Web. Visualization of SGML documents and navigation through links is completed with the display of monuments as spatial objects on maps and navigation through the geographic space. Queries on the contents and the structure of documents are enriched with spatial criteria on the location of monuments. We study the problems raised by the integration, we propose some possible solutions, and we describe the current implementation.

3. Extending User Interaction

The user interacts with two distinct system components : a SGML document server and a GIS map server. (Figure 1).

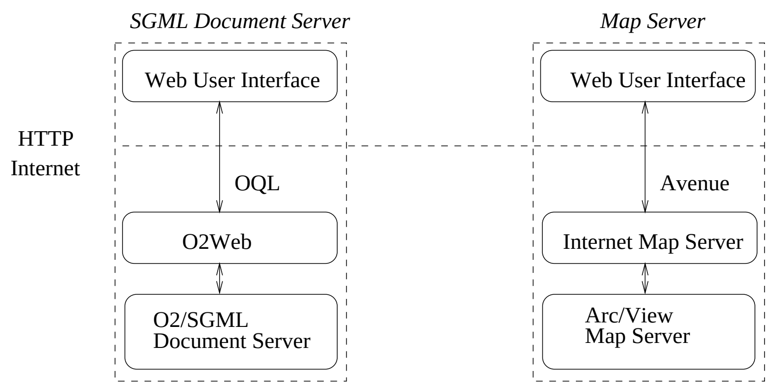

FIGURE 1. O_2/SGML and ArcView

The SGML Document Server stores inventory documents and folders as complex objects in some O_2 object-oriented database. The “Inventaire” project has adopted the SGML standard [18] for the internal representation of documents and folders and uses Euroclid’s O_2/SGML system [24] for the storage of these documents in the O_2 object-oriented DBMS. The management of structured documents is based on O_2’s persistent objects, on its powerful OQL query language and on its O_2Web interface. The user interface is typically a standard Web browser (e.g. Netscape) and communicates with O_2 via the O_2Web interface. This interface allows to the publisher the creation and customization of HTML documents from complex objects. Object relationships are translated into virtual hypertext links (URLs) encapsulating OQL queries which are evaluated at link traversal. The user can (1) display SGML documents describing buildings and artifacts, (2) navigate through documents connected by hypertext links, and (3) query the contents and the structure (e.g. title of the first section) of documents and folders using the OQL query language [13].

The Map Server stores maps and spatial objects based on the location and the extent of monuments. Spatial data handling is realized with ESRI's ArcView System. The Web interface is implemented by the ArcView Internet Map Server (AVIMS). As for the Document Server, the user interface is a standard Web browser providing the user with (1) the display of thematic maps (administrative regions, cities, districts, buildings, etc.), (2) navigation in thematic maps, using zoom and pan operations, and (3) evaluation of spatial (intersection, distance, etc.) and relational SQL queries using the Avenue script language.

It is easy to see that the integration of these functionalities not only represents the sum of the both user environments but adds new functionalities to the user interaction model :

Geo-referenced Document Browsing :: Spatial relationships between documents and spatial objects are converted to bi-directional hypertext links for obtaining the documents corresponding to some spatial object or vice-versa. For example, a user might first display a map of Paris, zoom into the third district and then click on the graphical representation (button) of some spatial object, e.g. the Museum of the Conservatoire National des Arts et Mtiers, for displaying all documents describing this building. This mechanism "synchronizes" the information displayed by both interfaces (documents and maps).

Spatial Document Querying :: Spatial relationships might be exploited for querying both SGML documents and spatial maps simultaneously. For example the user might ask to display all spatial objects corresponding to museums in the third district of Paris. In fact, this corresponds to the dynamic definition of map layers depending on the document contents. Spatial selection of documents (e.g. display all documents describing churches of the 15th century at a distance of less than 500 meters to the Louvre museum) is also possible.

Each system has its own specific Web user interface for browsing and querying data. Therefore, the problem of integrating structured documents and maps has be handled at the data and the user interface level. In our case, the data model and the Web user interface for the two system components (SGML and GIS) are quite complex and very different in nature. Therefore, it is very difficult to build a system for browsing spatially located structured documents by only extending one of the components. Displaying, browsing and querying data is very different for structured documents and for maps. Actually, ArcView stores non-spatial data in relational tables, but this is not enough for querying and browsing SGML structures. In the same way, a structured documents system based on an object-oriented database could store some spatial data (points, lines, ...) or even maps, but lacks the support for spatial queries and map browsing.

In conclusion, a system that manages spatially located SGML documents cannot discard one of the components without a significant loss of functionalities.

4. Two-Level Interoperability Architectures

In this section we will describe an architecture for integrating two commercially available software components, i.e. a SGML document server based on O_2 and the ArcView Geographic Information System.

4.1. **Partial data integration.** During the past several years an important effort on standardizing application interfaces has been undertaken. Among these standards, the most popular are OMG/Corba [21] for general object services, JDBC/ODBC [23] for relational DBMS and ODMG [11] for Object-Oriented DBMS. All of these standards are based on uniform logical data models for describing and exchanging data between different applications. The database standards also provide query language interfaces (SQL and OQL) for querying external databases.

The O_2 DBMS implements a number of standard interfaces (e.g. ODMG, ODBC, Java Binding) for integrating external application software with O_2 database functionalities. ArcView can store spatial and non-spatial data in commercially available relational DBMS (Oracle, Sybase) via ODBC. A two-tier architecture using the ODBC standard for connecting O_2/SGML and ArcView is shown in Figure 2. In this architecture, O_2 and ArcView can

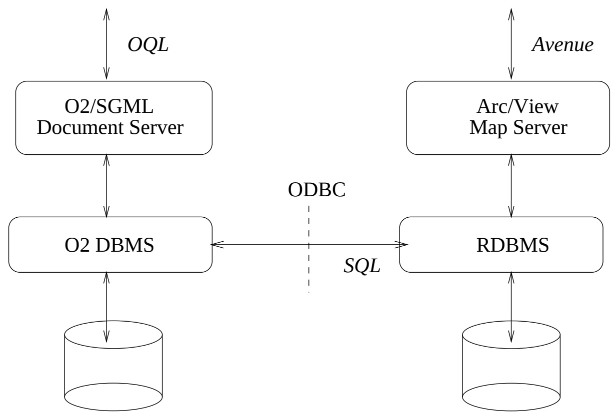

FIGURE 2. Two-Tier Architecture : ArcView's relational DBMS and O_2 access external data via the ODBC interface.

exchange SQL queries. Whereas this feature is useful for the evaluation of simple queries on external relational tables (SQL via ODBC), it is insufficient for more complex queries on both SGML documents and geographical maps. For example, it is not possible to find all photos of churches at less than 100 meters from the Seine river at Paris. This query has to be decomposed into two complex subqueries. The first subquery is an OQL query on the contents and structure of documents and finds all photos within documents describing churches. The second subquery is a spatial restriction of the distance between churches and the Seine river and must be evaluated by ArcView.

Another problem which is not solved by this architecture concerns the user interface. Since both Web interfaces (O_2Web and AVIMS) are specially conceived for the underlying data structures they are insufficient for browsing and querying external data such as SGML documents in the case of AVIMS or geographical maps in the case of O_2Web. We will present a solution to this problem in the following section.

4.2. **User interface integration.** The approach proposed in this section is based on the fact that complex data needs adapted user interfaces which are strongly-coupled to the underlying data structures. In order to display and to manipulate both structured documents and spatial data, one needs to integrate existing user interfaces. Extending a SGML/HTML interface to display and navigate through maps or adapting a GIS interface to display and navigate through SGML documents may imply a significant implementation effort. The reasonable method is to combine within a single user interface the existing SGML and map interfaces.

The proposed architecture is described in Figure 3. The Document Server and the GIS are both accessed through their own Web user interface which are synchronized by some global synchronization mechanism. At a given time, the user works within one of the two environments and is able to switch to the other one while keeping up the context. Typically, the user browses and queries SGML documents, and asks to display on the map the location of the artifact described in some displayed document. Reversely, the user may ask some spatial queries to the GIS and then access a SGML document by selecting a point on the resulting map.

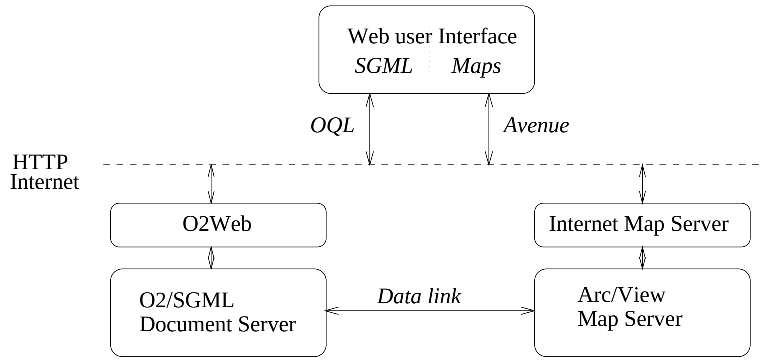

FIGURE 3. User Interface Integration Architecture

The global user interface enables the connection between the SGML Document Server and the Map Server by using an implicit data link. Each document within the Document Server has a unique, implementation independent identifier (e.g. the value of an attribute). The same value identifies the corresponding spatial object within the GIS. The connection between documents and maps is based on this unique identifier. The global interface keeps the context of the browsing process by storing the identifiers of current accessed objects (in structured or spatial form).

Keeping the current context of browsing within the interface allows an easy switching from structured documents to maps. The same identifiers composing the current context may be translated into spatial objects on maps or into documents. This favors an user-oriented strategy for asking complex queries on both document contents and location. For example, the user is searching for photos of 15th century churches within a distance of less than 10 kms of the A6 highway. He will first ask the GIS for monuments at less than 10 kms of the A6 highway. The result of this search is displayed on the map and the corresponding identifiers will form the new context. The user switches then to the SGML interface and ask to the Document Server only the photos of selected monuments that are 15th century churches. Of course, the way this query is processed depends on the way data is distributed between the GIS and the Document Server, but the principle does not change. For example, if the GIS stores some additional information about monuments (e.g. type of monument, century), the first query is more precise : find 15th century churches with the given spatial condition.

In conclusion, the interface is an active participant to the browsing and querying process. By storing the current context, it allows a transparent communication between its two data-specific parts. More functionalities can be added to the interface by using a vector representation of maps (currently, the ArcView Web interface uses JPEG images for displaying maps). In this case, selecting a spatial object or highlighting the location of a document on the map can be done locally, i.e. within the user interface client.

The main disadvantage of this approach is that complex queries (concerning both document contents and location) have to be split by the user into a spatial part and a structured document part. Future work will consider architectures for avoiding this drawback (see Section 6).

5. The "Inventaire" Prototype

Several prototype versions for consulting inventory documents through the Web were developed for the "Inventaire" project. The initial focus was directed to the creation of the O_2 SGML Document Server. A SGML→O_2 filter translates the SGML document structure (the DTD) into a O_2 database schema and transforms SGML documents into O_2 persistent objects. The O_2 solution has the advantages of a traditional database approach (persistence, transactions) and provides a powerful query language (OQL). The main drawback is that some natural SGML queries (e.g. searching in all the levels of folders containing a document, searching in all the fields called "Title") have no direct correspondent in OQL and must be implemented by using O_2 methods, a full-text index extension or an extension of OQL as described in [12].

O_2Web can execute any OQL query embedded into a CGI script call. O_2Web sends the query to the O_2 Server and transforms the result into a HTML page. By default, each object attribute is displayed by its name and value and each object reference by a hyperlink. Specific O_2Web methods allow to customize the HTML presentation. This feature is used in the "Inventaire" Document Server to present all the contents of a SGML document on the same page such that only links to other SGML documents are presented as hyperlinks.

The geographic aspects of inventory documents were not considered in this first prototype version. The next step was the introduction of maps and the use of points to represent monuments on the map. The first attempt was a monolithic approach, based on the extension of the O_2 Document Server. Each document had a location attribute (X and Y coordinates), used to display a point on a raster map. Maps were stored as bitmap images with attached geographic coordinates. A fixed hierarchy of maps allowed some simple form of geographic navigation at various levels of detail.

The poor spatial browsing and querying functionalities of the second prototype revealed the need of using a GIS. The current prototype uses ESRI's ArcView GIS and its Web interface ArcView Internet Map Server. The advantage of the interface oriented integration is that the existing O_2 SGML Document Server is reused with minor user interface modifications. The ArcView GIS Server stores several layers of French vector maps (administrative borders, roads, rivers,...) and the spatial inventory data about monuments. This spatial data is extracted from the same SGML documents that feed the O_2 Document Server.

For each spatial object, besides its geometry, ArcView may store and query usual alphanumeric attributes in relational tables. In the current prototype, partial data integration (Section 4.1) has been implemented by data replication. Instead of a dynamic SQL link between ArcView and O_2 (Figure 2) the main alphanumeric attributes (monument type, date, materials, etc.) are replicated in O_2 and ArcView's relational DBMS. This data duplication provides an extended power to the Map Server, because the user may ask both spatial and alphanumeric queries within the map interface. However, for complex queries on SGML documents, the user must use the SGML Document Server interface. Data coherence between the GIS and the Document Server is guaranteed by the fact that the only way to modify underlying databases is by simultaneous importation of SGML documents.

The Web interface for the ArcView GIS is ArcView Internet Map Server (AVIMS), installed as a software library (called *esrimap*) on a NSAPI/ISAPI compatible Web server. The access to the ArcView GIS is done by launching internal ArcView application scripts, written in the Avenue script language. Scripts implement application behavior within ArcView, by using any of its GIS capabilities (map navigation, spatial queries, etc). Scripts return a flow of data to the Web client which displays the result. AVIMS provides Web client software with HTML, Java or ActiveX access for Web clients to ArcView. The existing prototype uses the Avenue script language for generating raster maps (JPEG images) included in standard HTML documents. A Java interface, based on the AVIMS MapCaf applet, is currently under preparation.

The user interface (Figure 4) combines the Web user interfaces for ArcView and for the O_2 Document Server. The GIS part of the user interface allows for map browsing by zooming and panning, spatial and alphanumeric queries, display of query results on the map and identification of objects. Selecting an object on the map will display the corresponding document in the structured document browser. Reversely, the user may display on the map the location of the current document in the SGML browser. The current user interface has several limitations, which will be eliminated in the Java version - notably the visual interaction with maps. Also the global browsing context, limited now to one document identifier (the current one) in both the map and the SGML interfaces, will be extended to the current selection (a set of identifiers). This will allow users to use the result of a document query in order to restrict it via a spatial query in the map interface (and vice-versa).

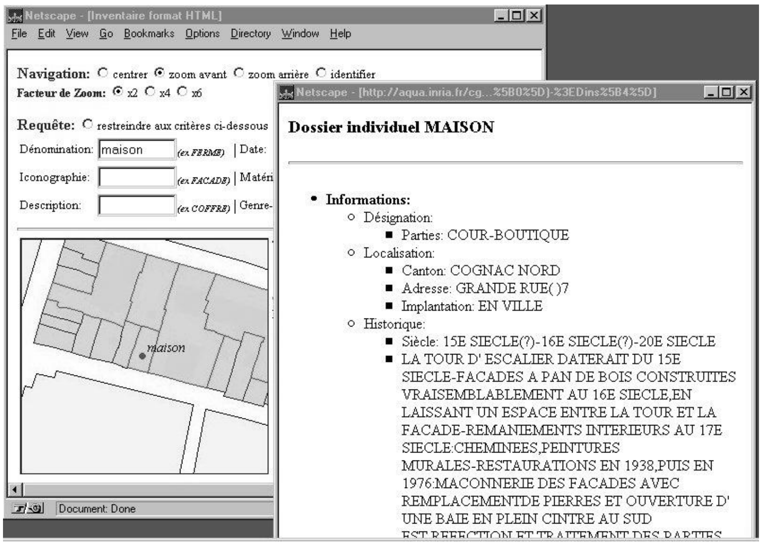

FIGURE 4. Screen Snapshot

The screen snapshot shown in Figure 4 is the result of several user actions. The user selected a geographical zone of interest by zooming and panning a thematic map with French administrative borders. The selected zone displays a part of the city of Cognac.

Afterwards she/he asked the Map Server to display all points corresponding to houses built in the 15th century. The new map is the result of an overlay of the old map and the query result. By clicking on the point with label *maison*, the user obtains the SGML document displayed in a different window.

6. Future Work - The Mediated Perspective

A different solution to the problem of integrating software components is the definition of a mediator-based architectures [25]. where applications access data via data access providers [9] which play the role of *mediators*, global layers [22] or master components [2] Mediators break the strong coupling between servers and clients, caused by low-level interfaces allowing only restricted forms of abstraction. They are generally based on common data models restricted to some application domain and include various information processing tasks like format conversion, data access, selection and integration. These tasks might be implemented only partially and it is possible to classify integrating architectures according to the number of operations available [2].

An important mediator task is to decompose and distribute client requests to the different wrappers and reassemble their responses. Figure 5 shows a possible mediator based three-tier architecture for integrating O_2/SGML with ArcView.

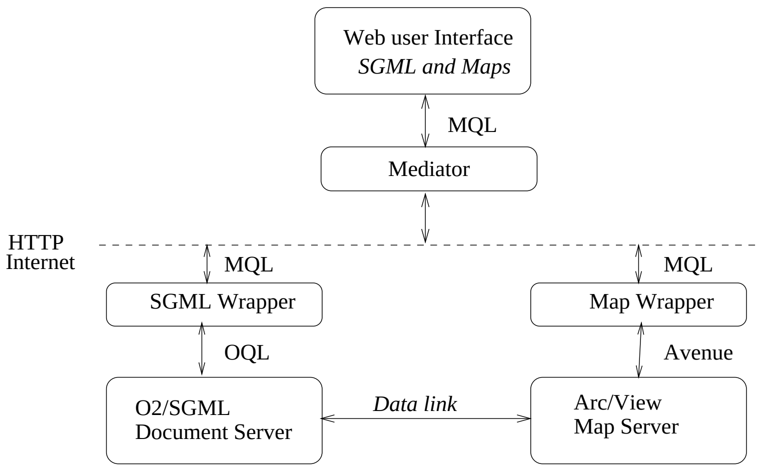

FIGURE 5. A Mediator Based Architecture

This architecture solves the issue of the evaluation of the complex queries involving SGML documents and geographical maps. The mediator component is responsible for the creation of a correct and efficient query execution plan and the integration of the obtained results. The main issue is the definition of a mediation model and query language which are general enough to describe such diverse data as SGML documents and geographical maps and specific enough to be implemented efficiently. Recent work on data mediation proposes different approaches based on the ODMG [10] standard, on description logics [7] or semi-structured data models [4]. The authors are not aware of any evaluation or implementation using one of these approaches for integrating spatial data with other complex data structures. Reference [5] describes a spatial mediator architecture based on the ODMG standard. Nevertheless strongly typed data models such as ODMG seem to be too rigid for the integration of complex data. The approach based on a semistructured view of data seems to be promising for structured SGML/HTML or XML documents. Similar to these standards based on the exchange of self-describing data it might be interesting to evaluate spatial data exchange formats such as the Spatial Data Transfer Standard (SDTS) [1] for a semistructured mediation approach.

7. Related Work and Conclusion

A large number of spatial data services are accessible on Internet. [1] These interfaces can be classified by the underlying data representation (vector versus raster) and by their local processing capacity (active Java applets versus passive HTML ISMAP [20, 8]) The ArcView Web interface used in our prototype uses raster data based on ISMAP. A Java applet interface based on vector data is described in [5].

Information discovery is a major issue for users browsing the World-Wide Web. Our prototype can be considered as a kind of Spatial Digital Library [19, 6] for patrimonial data. On the one hand, the document subsystem represents a catalogue service containing descriptive meta-information for spatial data and, on the other hand, it is possible to find relevant documents with respect to the spatial properties of the buildings they describe. This allows users to explore available information from different points of view.

The SIRO-Spatial Information System (SIS) [3] proposes a mediator based architecture for integrating raster and vector based data sources. The user's view of the system and the system-internal view are separated by an executive mediator module using meta-information about about data sources and users for generating efficient processing plans. The user interface problem is solved by an extra component devoted to the transformation and visualization of heterogeneous data sets according to an existing user interface. Whereas this approach is possible for different representations (e.g. vector and raster) of information of the same application domain (e.g. spatial maps), it is insufficient for information with different semantics (e.g. SGML and maps).

The Open Geodata Interoperability Specification (OGIS) framework [9] achieves "data interoperability" by an extensible information model describing real world space/time phenomena at different abstraction levels (real-world, specification, implementation). This framework has been conceived for spatio-temporal data and does not address the problem of integrating complex data from different application domains.

The SAND (Spatial And Non-spatial Data) system implements an open environment for developing applications involving both spatial and non-spatial relational data. Reference [16] describes optimization strategies for spatial query processing providing equal opportunity for both the spatial and non-spatial component to participate in query processing and optimization. Query execution plan generation and optimization will become a key issue for the implementation of a mediated architecture (Section 6)

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