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Using Semantic, Geographical, and Temporal Relationships to Enhance Search and Retrieval in Digital Catalogs

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Abstract
The amount and quality of information available on the Internet increases steadily. To search for information, users are provided with search engines which often return unsatisfactory search results. Against this background, digital catalog systems are becoming more and more popular. Unlike earlier search engines, they contain information about information (meta-information) available on the Internet or in the holdings of digital libraries but not the information itself. Users can benefit from these systems in two ways depending on what information is modeled in them. Firstly, these systems allow for new types of queries; secondly, the quality of retrieval results is improved. This paper sets out how semantic, geographical, and temporal relationships can be integrated into digital catalog systems and how these relationships can be used to enhance search and retrieval processes in such systems. The presentation covers both concepts and a comprehensive description of a digital catalog system which is already used by environmental agencies.

Keywords
Digital Catalog Systems; Semantic, Geographical, and Temporal Relationships; German Environmental Information Network

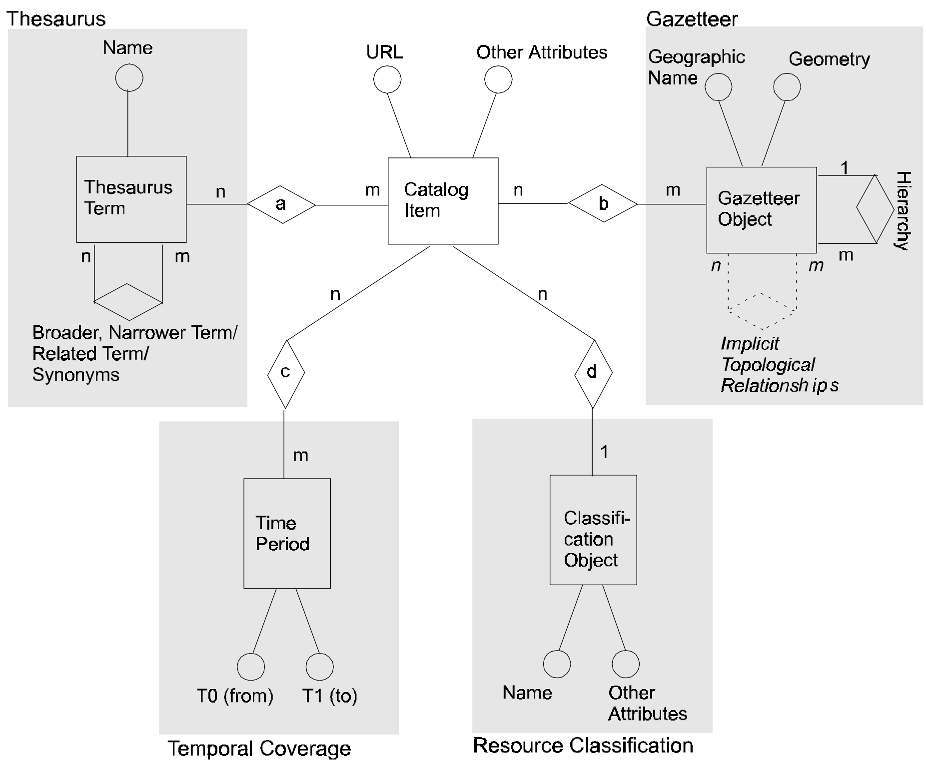
1 Introduction and Motivation

Catalogs are used to facilitate the identification, location, access, and use of items in the holdings of libraries. In traditional libraries, different ways of organizing catalogs exist. For example, alphabetic cataloging is concerned with organizing catalog items in an alphabetic order while systematic or subject cataloging is concerned with classifying the subject matter of each catalog item. Historically, book catalogs were the first kind of catalogs. They were supplemented by digital catalogs, referred to as Online Public Access Catalogs (OPAC), in the early 70's. With the success of the Internet and World Wide Web, most of the OPACs were made Internet compliant and are now accessible using common Web browsers. Since OPACs have their historical roots in traditional book catalogs, only little attention was paid to new techniques for digital cataloging. However, there exist standards to ease the sharing of catalog items among institutions (e.g., MARC format). Also, protocols have been introduced and standardized to allow communication between library systems (e.g., Z39.50 [Z39.50], Dienst [LaDa95]). From the perspective of digital libraries, however, only little effort was spent on digital catalogs. A typical example is the Dortmund Digital Library System DogitaLS1 [ToAl97] in which only alphabetic and systematic catalogs are available even though modern technologies allow much more sophisticated concepts for digital catalogs. In [GlFo94], Gladney, Fox et al. summarize discussions from a previous workshop on digital libraries and provide definitions and characteristics of and requirements for digital libraries. Among other things, the requirements for digital catalogs as an essential part of digital library systems are mentioned. This topic, however, was not considered satisfactorily in the workshop on which the paper is based. Instead, Gladney, Fox et al. recommend renewed attention being given to digital catalogs "*...either by resurrecting ... or by constructing a fresh something* ..." [GlFo94, p.105]. One year later a first paper called 'Cataloging in the Digital Order' was published by David M. Levy [Lev95]. Levy mainly argues why powerful search, browsing, and indexing tools cannot obviate the need for digital catalogs. Levy's paper closes with a list of important questions. Both papers and particularly the open questions of Levy's paper motivated us to start research in that area. One result of our work is that we can suggest answers to most of Levy's questions (see section 5). Further, our research shows that the use of new types of relationships (i.e., geographical, semantic, and temporal relationships) in digital catalogs leads to a significant improvement in the quality of retrieval results. In our opinion, this contributes to the recommendation of Gladney, Fox et al. to construct a '... *fresh something* ...'. Further to concepts, we also refer to the on-going development for a German Environmental Information Network GEIN. GEIN provides a digital catalog system for environmental information resources which implements the different types of relationships mentioned above.

The remainder of the paper is set out as follows: Section 2 focuses on cataloging in more detail and introduces terms like geographical, semantic, and temporal relationships. It also elaborates the architecture of the digital catalog used in GEIN. In Section 3, we show how the use of our prototype can enhance search and retrieval processes in digital catalogs. Section 4 briefly sketches how the digital catalog system can be embedded and used in an Internet compliant setting. Related literature is discussed in Section 5. Our paper closes in Section 6 with a discussion, a brief outline of future research, and a list of suggestions for answers to Levy's questions from 1995.

2 The Architecture of the Digital Catalog

In 1996, the FAW Research Institute for Applied Knowledge Processing in Ulm, Germany, was commissioned by the German Federal Environmental Agency (UBA) to build a prototype for the German Environmental Information Network (GEIN). The core of GEIN is a digital catalog system which integrates a number of environmental information resources from German environmental administrations at state and federal levels as well as a number of other relevant information providers. The environmental information resources to be recorded can reside either on Intranets, on the Internet, or



Legend *a) semantic relationship* *b) geographical relationship* *c) temporal relationship* *d) classification relationship*

Fig. 1: Components of the Digital Catalog

TCP/IP compliant databases. GEIN serves as a German contribution to the pilot project Environment and Natural Resource Management (ENRM) of the G7 initiative for a Global Information Infrastructure (GII). UBA and FAW plan to continue the development of GEIN in a new project referred to as GEIN 2000. GEIN 2000 will be part of Germany's contribution to the World Fair Expo 2000 which will be held under the keynote theme "Humankind – Nature – Technology" in the year 2000 in Germany.

Unlike traditional catalogs, the information resources in GEIN are indexed by means of semantic, geographical, and temporal relationships. Before explaining these relationships in further detail, we would like to sketch the overall structure of the digital catalog.

As the entity-relationship diagram in figure 1 shows, the digital catalog consists of five main components. Each entry in the catalog is represented by a catalog item. Among others, a uniform resource locator (URL, i.e., an Internet address) at which the resources reside is stored with each catalog item. Semantic relationships are modeled by means of a thesaurus. A gazetteer (i.e., a geographical thesaurus) is used to model the geographical relationships of catalog items. Also, the digital catalog contains a component for modeling the temporal coverage of catalog items. Finally, a classification component allows the classification of the catalog items according to the type of the resources they record.

2.1 The Catalog Items

Catalog items contain meta-information on data, documents, Internet resources, methods, etc. available electronically on Intranets, on the Internet, or TCP/IP compliant databases. In addition, each catalog item has access to information about the organization which supplies the corresponding resource (c.f., Section 3.5).

2.2 The Thesaurus Component

We use the environmental thesaurus of the German Federal Environmental Agency [Bat94] for modeling semantic relationships between catalog items. The structure and multilingual extensions of this thesaurus are standardized by ISO 2788 and ISO 5964, respectively. Each catalog item has an n:m relationship to a thesaurus term. Thus, it is possible for each item to be associated with several terms and vice versa so that the same thesaurus term can be associated with different catalog items. The thesaurus serves two purposes: Firstly, it forms a repository of terms that can be used as keywords for indexing and retrieving catalog items. Secondly, semantic relationships between thesaurus terms are supported to allow for intelligent search and indexing techniques. Currently, the digital catalog supports associations with synonyms, broader, narrower, and related terms. In addition, the thesaurus component is equipped with a multilingual extension which is used in GEIN to support the indexing and retrieval of catalog items alternatively using German and English vocabulary.

2.3 The Gazetteer Component

A gazetteer is a structured geographical index, in which each element has a geographical name and a geometry (e.g., a polygon described by coordinates such as longitude and latitude). Through associating catalog items with gazetteer objects, catalog items can be searched for based on their geography. Particularly, in environmental settings, it is important that the catalog items have an n:m relationship to gazetteer objects. For example, an environmental directive or law can have more than one geographical relationship (e.g., if it is valid in several geographical regions) and vice versa, in one geographical region several different environmental laws can be valid. Currently, various layers of gazetteer objects including administration units (German councils, districts, states, neighboring countries), water bodies (lakes, rivers, canals) or topographical map sheets can be used for geographical references. Like semantic relationships in a thesaurus, explicit and implicit semantic relationships can exist between gazetteer objects. An explicit hierarchical relationship is provided to model hierarchies of gazetteer objects such as the administration hierarchy inherent in the layer of administration units. Topological relationships between gazetteer objects are represented implicitly in the gazetteer (this is indicated by the dotted line and the italic font in the entity-relationship diagram for the gazetteer in figure 1). The gazetteer supports topological relationships such as *encloses*, *is enclosed by*, *is adjacent to*, and *overlaps*. By comparing the geometries of the respective gazetteer objects, these relationships can be computed on demand whenever they are needed. These implicit topological relationships between gazetteer objects can be exploited for geographical indexing of and searching for catalog items (e.g., by using geometries or geographical names).

Unlike a thesaurus, where each new contribution must be evaluated on the basis of the existing content and where explicit relationships must be established with the existing contents of the thesaurus, this computational approach allows us to keep the efforts required by suppliers to enter new catalog items in the gazetteer as low as possible.

2.4 The Temporal Coverage Component

Temporal coverage allows the use of temporal data as a basis for recording and analyzing variations over time. Each item in the digital catalog has an n:m relationship to a time period or, as a special case, to a point in time. For example, since the publication date of an environmental law normally differs from the date at which it becomes valid, several time periods are required to describe the temporal coverage. Vice versa, two different environmental laws (i.e., two different catalog items) can have the same point in time at which they become valid. Currently, however, the semantics of a temporal relationship is left undefined. Thus, temporal relationships only express the fact that a catalog item is somehow related to a time period or a point in time.

2.5 The Resources Classification Component

Since different types of information are stored in the digital catalog, a component for the classification of resources is provided. This is helpful for the restriction of a search to a specific type of resource only. Among others, we differentiate between *reports* and *methods*. A common requirement is that data from existing environmental databases (e.g., measurement series and census data) should be recorded in an environmental digital catalog. However, it is impossible to index the huge amount of data elements stored in such databases. Instead, we prefer recording methods (e.g., a database query) and making them searchable and retrievable in the digital catalog. Hence, when users search for data from specific environmental databases they can be provided with database queries which retrieve the desired data. Methods can also serve as information sources by generating information from existing data. Examples are environmental simulations or statistical analysis functions.

3 Adding and Retrieving Catalog Items

In this section we briefly want to sketch how new catalog items can be added to the digital catalog. The emphasis, however, is placed on how users can search for items stored in the digital catalog. Various search criteria can be specified by filling in a search form. The result of a search is a list of information resources. By simply using the mouse, it is possible to activate detailed descriptions for every resource in the list. It is also possible to access the original information, as long as it resides on a server in the World Wide Web or a TCP/IP compliant database. An important search characteristic of GEIN is that users can freely decide how many relationships and what type of relationship they want to use for their search. For example, it is possible to search for catalog items using keywords from the thesaurus only.

3.1 Adding New Catalog Items

The entry of new descriptions of information resources to the catalog can be done best by the suppliers themselves. The digital catalog system offers services which are, as far as possible, automated. The current implementation of the GEIN system already

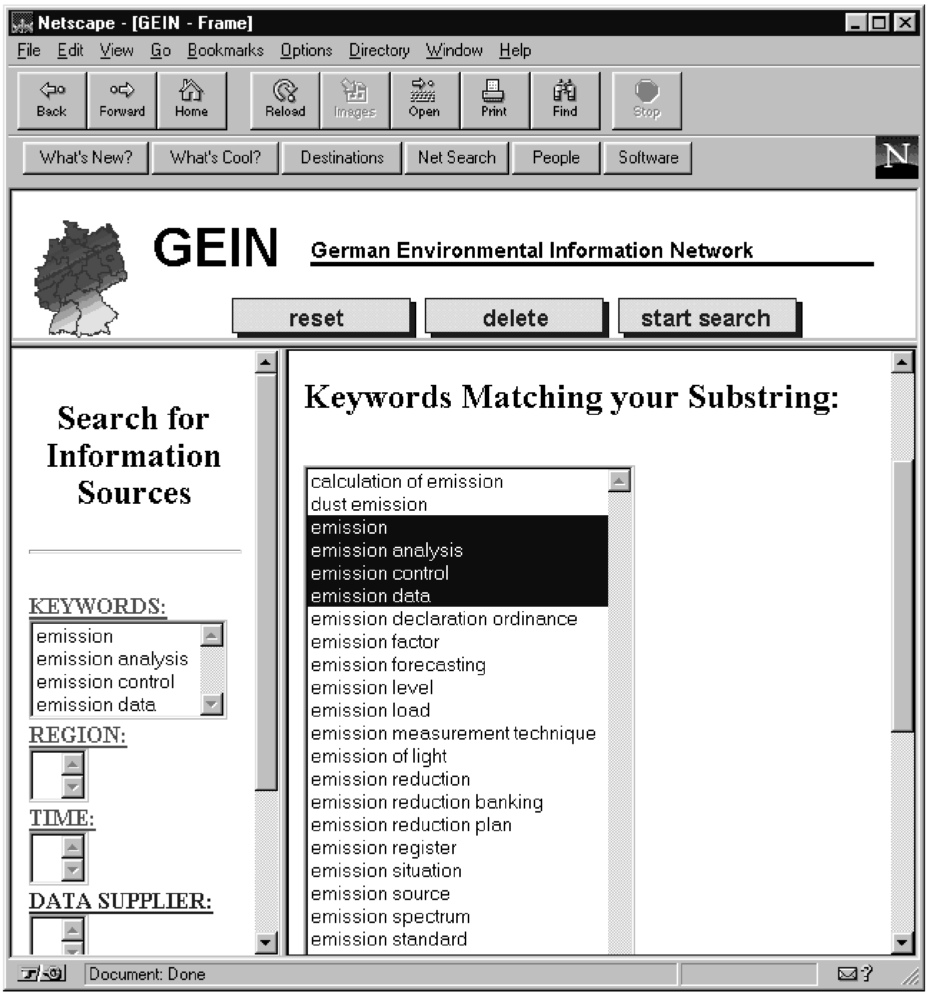


Fig. 2: Selecting Semantic Relationships for a Search

associates keywords with textual documents by comparing the texts in question with the environmental thesaurus. The indexing of geographical and temporal references with the help of the gazetteer and the temporal component is planned to work analogously. Currently, this must be done by the information suppliers through Web compliant services but without any automated support.

3.2 Search Using Semantic Relationships

A keyword search in the digital catalog can be performed by specifying terms from the environmental thesaurus. The system can provide users with appropriate terms by means of a component which automatically generates a list of thesaurus terms that contain a specific substring.

Figure 2 shows a list consisting of all thesaurus terms that contain the substring 'emission'. Users can choose the terms they want to use in their search by simply

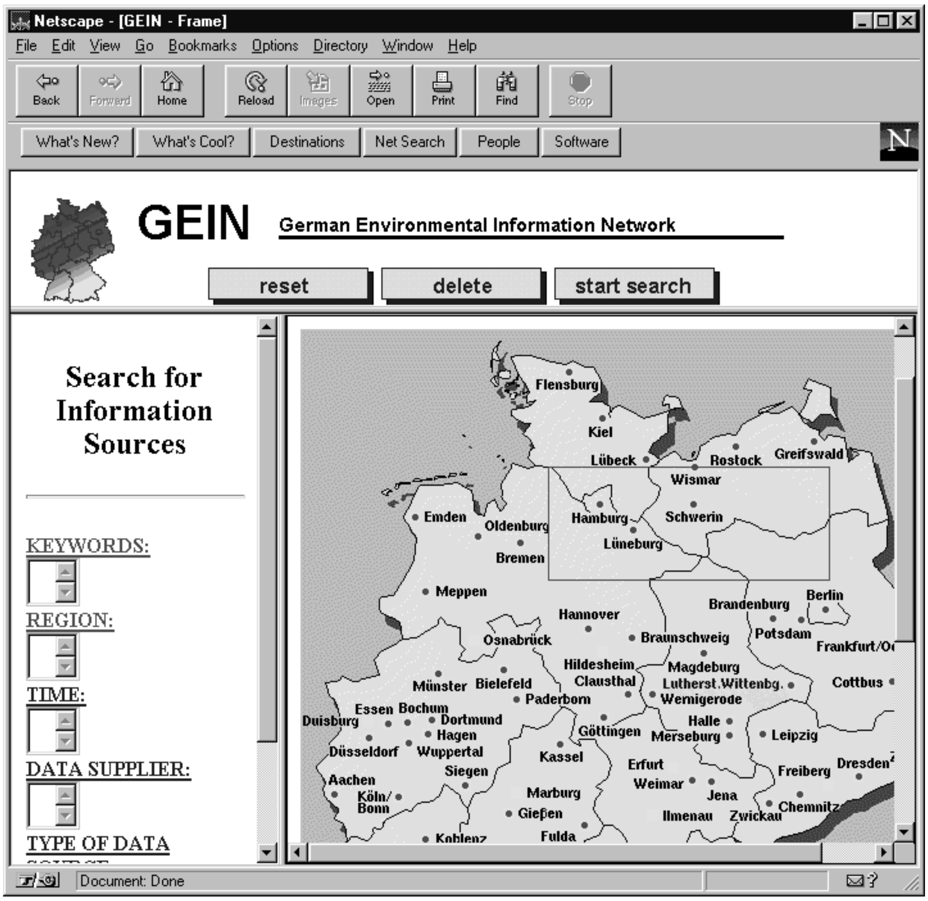


Fig. 3: Selecting a Geographical Relationship for a Search

selecting them with the mouse. Selected descriptors are listed in the keyword field on the left. Further, users can access terms which are semantically related to a specific descriptor. This list comprises all synonyms, broader, narrower, and related terms of the descriptor chosen (this is not shown in figure 2).

3.3 Search Using Geographical Relationships

Geographical relationships can restrict the search to resources which are related to a geographical region. For example, this is helpful if users are interested in environmental laws that are valid in a specific region only.

The digital catalog system offers two ways of defining a geographical relationship for a catalog item to be searched for. Similar to choosing keywords for semantic relationships, a browser for gazetteer objects supports users in choosing geographical names (this browser is not displayed in figure 3). To each gazetteer object shown by its name, the browser can also provide users with topologically-related gazetteer objects. In particular, users can choose further objects describing geographical regions which enclose, are enclosed by, are adjacent to, or overlap the geographical region

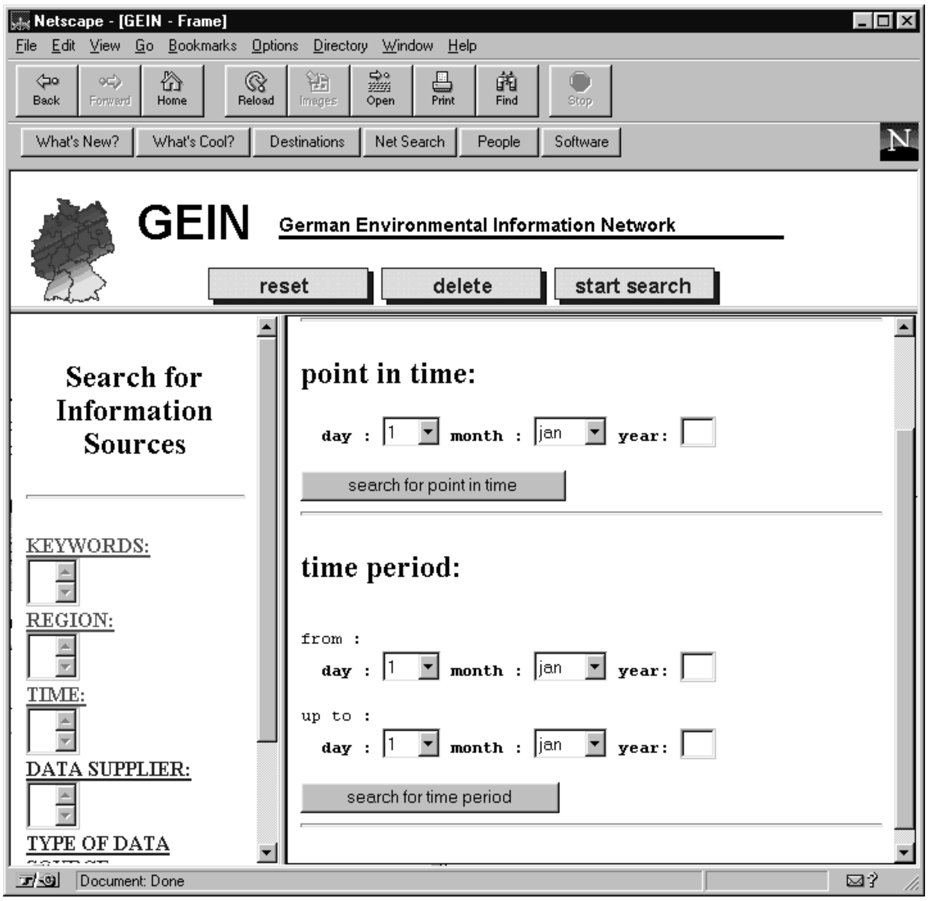


Fig. 4: Defining Temporal Relationships

represented by the original gazetteer object. In addition, it is also possible to define a geographical relationship interactively. This is shown in figure 3, where a user has defined a rectangular geometry to which the catalog item to be searched for should be related. Similar to geographical names, gazetteer objects that are geographically related to the interactively chosen geometry can be selected and taken into consideration for a search.

3.4 Search Using Temporal Relationships

Temporal relationships can be used to restrict the search to resources which are related to a given point in time or time period. For example, this is desired if users are only interested in environmental laws that are valid by a certain point in time. Figure 4 displays the user interface for defining temporal relationships.

3.5 Combined Search and Further Selection Possibilities

The previous sections have only given some examples of how users can define and perform a search query with one of the possible relationships. Basically, the same steps must be taken, if several relationships are to be used for a combined search query. Apart from searching with respect to one relationship only (e.g., a simple keyword search), four combination possibilities for combined search queries exist. We want to give some examples to show that each of the combinations makes sense and is important for end-users.

Query with semantic and geographical relationships: *Find catalog items on air pollution which are related to the State of Baden-Württemberg.*

Query with semantic and temporal relationships: *Find catalog items on air pollution which are related to April 1st, 1997.*

Query with geographical and temporal relationships: *Find catalog items which are related to the State of Baden-Württemberg and to the time period 1990 - 1997.*

Query with semantic, geographical and temporal relationships: *Find catalog items on air pollution in the State of Baden-Württemberg which are related to June 1st, 1997.*

Further to the possibilities mentioned above, users can also choose that they are only interested in data from a certain data supplier (c.f. Section 2.5). Such a feature allows end-users to restrict their search to data suppliers that provide the type of information in which end-users are interested. In addition, users can define the type of data which a catalog item describes. For example, this is useful, if users only want information on reports available on the Internet but do not want information on resources stored in databases.

4 Technical Aspects

GEIN is a digital catalog system which was developed using standard Internet technologies, such as forms written in the Hypertext Markup Language (HTML), PERL scripts, and Java. We are using an Oracle database to store all catalog items in the digital catalog. The following figure depicts how the digital catalog system can be integrated in an Internet compliant setting comprising library holdings and how users can work with the catalog system in such a setting. The catalog system runs on an Internet compliant server with a connection to the database which stores all catalog items. It provides forms through a Web client to the user interface. Users can query the digital catalog, c.f. (1) in figure 5. The catalog system returns as a result a list of catalog items which match the query, c.f. (2) in figure 5. As far as possible, the catalog items provide hyperlinks to the actual resources. These resources can be data from a database or documents, reports, etc. which may reside on any Internet compliant information system, such as a Web server. Users can follow the links to these resources, c.f. (3) in figure 5, and access the holdings through a Web interface. As a result the actual resource is returned to the user interface, c.f. (4) in figure 5.

To access data from relational databases, we designed a software tool called WebQuery. WebQuery is a generally applicable software which makes possible the installation of network services, referred to as selectors, which allow for the retrieval of information from a database on specific topics. These selectors are presented to the user as data entry forms through a Web browser. WebQuery transforms the content entered on the form into a database query. The result of such a query is shown by the Web browser as a dynamically-generated HTML document.

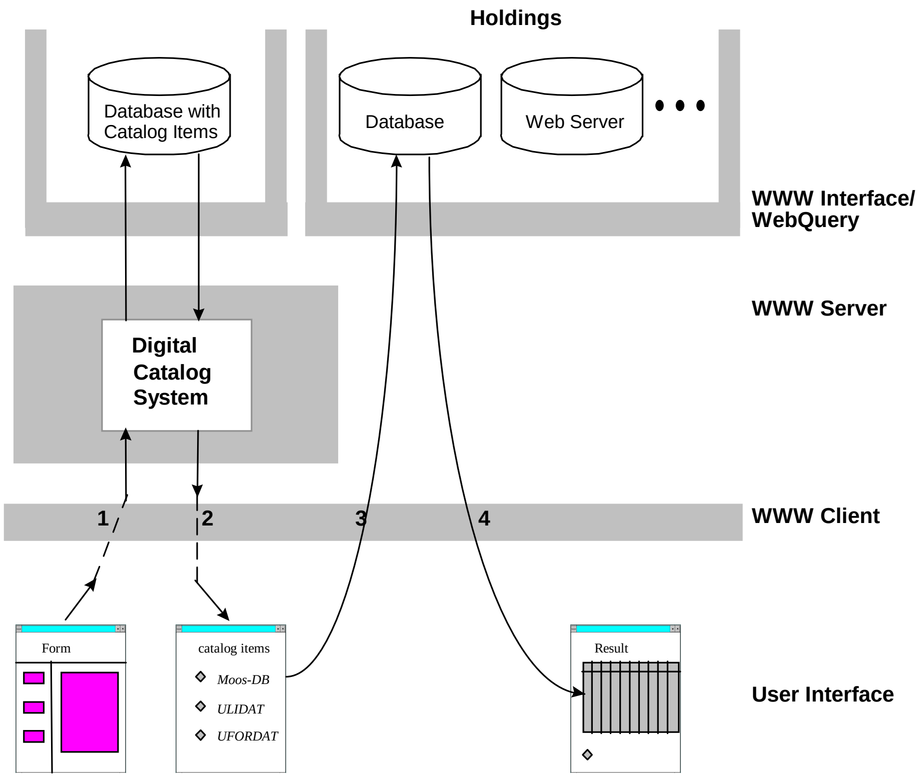


Fig. 5: The digital catalog system in an Internet compliant setting

5 Related Literature

The Alexandria Digital Library (ADL) [ADL97a] is a project which is closely related to ours. The ADL deals with problems of distributed digital libraries for geographically-referenced information. There are some similarities but two main differences between ADL and GEIN. A similarity is that, as with GEIN's gazetteer, in order to query ADL, users can either type in a geographical name in the gazetteer or interactively select a geographical region in a map browser.

The first main difference to GEIN is that ADL is a digital library system which has its own holdings while GEIN is a digital catalog system in which the resources recorded are not under its control. The second main difference is that ADL provides the concept of features (e.g., airport, swamp). Feature terms serve the purpose of describing what type of place a particular place name stands for. It is possible to use more than one feature type for any particular place. A thesaurus of a geographical feature type terminology is under current development. It supports broader terms, narrower terms, related terms, and synonymous terms for feature types. The thesaurus is also designed for searching so that users can search for "marshes" and find out that "wetlands" is the term to use and also that a broad search can be carried out using “hydrographic features”. A first draft of this thesaurus is available at [ADL97b]. We do not have features and a thesaurus for feature type terminology in GEIN, instead we have a layer concept to model relationships between gazetteer objects. It allows the use of German councils, districts, states, neighboring countries, lakes, rivers, canals, and important highways for geographical references of catalog items. Both, implicit topological relationships, such as *encloses, is enclosed by*, *is adjacent to* and *overlaps,* and explicit topological relationships, for example the administration hierarchy, can be used to enhance search and retrieval processes. For example, if users looked for catalog items which are geographically related to a state, the system could also retrieve items which are geographically related to the districts within that state.

Since there are some parts where ADL and GEIN are closely related to one another, one might be interested in an assessment on how the two systems might be combined with each other. As we see it, GEIN is a digital catalog system which is very loosely connected to and, thus, very independent of the holdings it catalogs (c.f. figure 5). This means that documents of arbitrary holdings can be cataloged with GEIN. By contrast, the ADL is a digital library in which different components, such as catalog, gazetteer, holdings etc. exist. Apparently, these components are closely connected to one another and particularly to the ADL holdings. Hence, a scenario for a combination of GEIN and ADL could be that GEIN serves as an external catalog system for the holdings of ADL which does not need to have a close connection to the holdings and can be run separately from the actual digital library.

The mission of the U.S. Geological Survey (USGS) [USGS97] is to provide geological, topographical, and hydrological information by means of maps, databases, and descriptions and analyses of the water, energy, and mineral resources, land surface, dynamic processes of the earth etc. The National Geospatial Data Clearinghouse (NGDC) [NGDC97] is a node within the USGS that provides information about geospatial data. The search features of NGDC are consistent with those of GEIN but we have not found a way of restricting the search to a specific type of document or to a specific supplier.

Like GEIN, the Florida Growth Management Data Network Coordinating Council (GMDNCC) [KaJu95], is directed toward state governmental agencies where fully distributed metadata collection and access services within a network environment are necessary. In GMDNCC, geographical data is viewed using a geographic information system (GIS). Currently, we only have a connection to external tools, if a Multimedia Internet Mail Extension (MIME) type is attached to the data. We are preparing the development of a component for GEIN which allows users to view retrieved data by other tools than a Web browser.

One result of the OCLC Metadata Workshop Series [OCLC97] has been the Dublin Core Metadata Element Set, proposed as the minimum number of metadata elements required to facilitate the discovery of document-like objects in a networked environment such as the Internet. A second result has been the Warwick Framework, a container architecture for aggregating logically, and perhaps physically, distinct packages of metadata. Since our catalog items record environmental data only, we preferred using metadata standards for this type of information resources. Therefore, in the meta-database which underlies GEIN we followed the architecture and ideas of the German Environmental Data Catalogue (UDK) [GüLe96].

6 Discussion and Outlook

The current implementation of GEIN does not yet provide a foolproof tool for adding new geographical and temporal items to the digital catalog although Web compliant services concerning the entry and maintenance of meta-information exist. These services, however, are not yet suitable for inexperienced users. Hence, we will place more emphasis on this issue in the near future.

Like many others, we are also affected by the problem that resources in our digital catalog system are not under the control of that system. This means that the digital catalog can contain references to resources that have already been moved to another site or have been deleted or renamed. Unlike other digital library systems with links to external resources (e.g., DogitaLS1 [ToAl97]), GEIN does not contain a component which checks resources for availability. Users consider this to be a major shortcoming of the current version.

We are planning to focus more on digital multi-catalog systems in the near future. Multi-catalog systems are an important issue in a recent project that aims at an Environmental Locator and Communication Service (German acronym: VKS-Umwelt) for the Intranet of the German Federal Environmental Agency [SeMo97]. The idea is to integrate a number of specialized digital catalogs rather than build one single 'universal catalog' in which as many resources as possible are recorded. The collection of catalogs should be connected to each other so that queries can be processed simultaneously in all the different catalogs. Our research in that area has already shown that a mediator is to be put in between the user interface also referred to as front-end and the digital catalog systems forming the back-end of the projected system. The mediator translates uniform search queries from the front-end into the query languages of each of the connected digital catalog systems at the back-end. Similar to this, the mediator unifies search results contributed by the catalog systems at the back-end before they are forwarded to the user front-end. We also believe, that HTTP lacks too many features to be used as transfer protocol for this approach. For example, in order to adapt uniform queries from the front-end to queries that will be understood by the digital catalog systems, the mediator needs to know what attributes it can search for in each of these systems. The most promising solution seems to be the use of Z39.50 or one of its profiles, in particular GILS [GILS97] or GELOS [GELOS97]. The mediator would serve as a Z39.50 client while each of the digital catalogs would serve as a Z39.50 server. Both communicate with each other to define what attributes the mediator can search for in each of the digital catalogs. Z39.50 or a Z39.50 profile would avoid that different names will be used for the same attribute in different catalogs (e.g., 'time period' and 'temporal coverage' as attribute names for the temporal coverage of the information resource). Besides multi-catalog systems, spatio-temporal extensions of the Z39.50 protocol such as provided by ISite [NeFu95], GILS, and GELOS will be taken into consideration for our future work.

The cataloging of dynamic documents is another important and still unexplored research field. Unlike [LeMa95] who define dynamic documents with respect to the validity of their content, we refer to documents as dynamic documents if they are generated on demand at the time users try to access them. As the most prominent example, dynamic documents are generated when users submit a query to a database and the document to be returned is constructed dynamically using the data of the query result. Since owing to their very nature, dynamic documents cannot be cataloged, we suggest the cataloging of the programs which generate them. A first approach towards that direction is described in [RiMa97].

In the context of multi-catalog systems, off-line retrieval might also become important for future digital library systems. By off-line retrieval we mean the possibility of submitting search queries as a batch job to one or several catalogs. This would be helpful for huge catalogs or catalogs that are distributed among several servers at different places in the world. In such catalogs searching can be very time-consuming and, thus, users may prefer an off-line search. The result can be delivered either to a user's web server or it can be sent by e-mail.

As pointed out at the beginning of the paper, the approach chosen suggests answers to questions asked in 'Cataloging in the Digital Order' [Lev95].

What sorts of materials will be cataloged? All types of materials will be cataloged. This includes physical documents (e.g., printed books, audio CDs), electronic documents, metadata on other catalogs, Internet resources etc. In contrast to earlier catalog systems, digital catalog systems can also catalog documents that actually do not exist but can be created at the time the user accesses them (i.e., dynamic documents).

How will digital catalogs differ from those we have today? Traditional libraries have alphabetical and systematic catalogues with restricted search features even in the OPACs. One of the most important benefits of digital catalog systems is that the quality of search results can be enhanced by exploiting geographical, semantic, and temporal relationships.

To what extent will these catalogs be based on existing standards, such as MARC and AACR? This will mainly depend on how many already existing catalog entries must be integrated in the digital catalog system. For example, in our system we were required to catalog data for which no catalogs existed at the time we started the project. Hence, we could define our catalog format without any restrictions. However, we strongly recommend the use of a standardized format since otherwise sharing of catalog entries among institutions will cause tremendous problems. In the multi-catalog approach, the catalogs should be at least compliant with Z39.50 and its spatio-temporal extensions, such as ISite and GILS.

Will there or could there be a universal catalog of digital materials? In our view, it will be a dead end if we try to build a universal catalog of digital materials. We rather suggest the further investigation of the idea of multi-catalog systems as mentioned above.

At present we do not have satisfactory answers to the questions *What skills will be needed to create these new catalogs? How will such skills be acquired?* We hope, however, that the other suggestions will provide further input to the discussion on digital catalog systems.

As we see it, our research contributes to an important topic in the area of digital libraries, namely digital catalog systems. With our system we can provide the research community with answers to important questions asked in 1995 by D.M. Levy. Also, the positive feedback from the users and suppliers as well as the prospect of extending the system for Expo 2000 indicates that our approach is a promising step towards the successful management of heterogeneous and distributed information resources.

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