# A Cultural Community Portal for Publishing Museum Collections on the Semantic Web

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**Abstract.** This paper presents a deployed semantic web application in the cultural domain: the semantic portal MUSEUMFINLAND. It is a demonstration of a community portal and a publication channel by which heterogeneous collection database contents of different museums can be published on the Semantic Web. By semantic web techniques, it is possible to make collections semantically interoperable and provide the museum visitors with intelligent content-based search and browsing services to the global collection base.

## 1 Why MuseumFinland?

Much of the semantic web content will be published using semantic portals[1] [14]. Such portals typically provide the end-user with two basic services: 1) a search engine based on the semantics of the content [1] and 2) dynamic linking between pages based on the semantic relations in the underlying knowledge base [5].

"MUSEUMFINLAND — Finnish Museums on the Semantic Web"[2] is a semantic portal that contains metadata from the collection databases of the National Museum[3], Espoo City Museum[4], and Lahti City Museum[5], and more content is being ported into the system. The application is intended for the public in the large to use.

The goals for developing the system were the following:

**Global view to distributed collections** It is possible to use the heterogeneous distributed collections of the museums participating in the system as if the collections were in a single uniform repository.

**Content-based information retrieval** The system supports intelligent information retrieval based on ontological concepts, not on simple keyword string matching as is customary with current search engines.

[1] See, e.g., http://www.ontoweb.org.
[2] http://museosuomi.cs.helsinki.fi
[3] http://www.nba.fi
[4] http://www.espoo.fi/museo/
[5] http://www.lahti.fi/museot/

**Semantically linked contents** A most interesting aspect of the collection items to the end-user are the implicit semantic relations that relate collection data with their context and to each other. In MuseumFinland, such associations are exposed to the end-user by defining them in terms of logical predicate rules that make use of the underlying ontologies and collection metadata.

**Easy local content publication** The portal should provide the museums with a cost-effective publication channel.

Figure 1 depicts the general idea. The goal is to make the distributed Finnish museum collections available on the web as a searchable and browsable WWW space of semantically linked pages, not as a traditional database query application. The MuseumFinland home page is the single entry point through which the end-user enters this island of the Semantic Web.

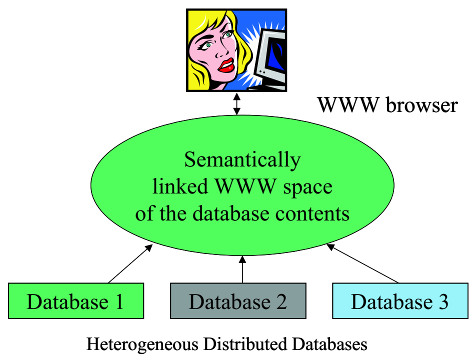


**Fig. 1.** The idea of the Finnish Museums on the Semantic Web system from a user's point of view.

In the following, the goals and solutions developed in our work are described. After this, main results of the work are summarized, lessons learned discussed, and directions for further research outlined.

## 2 Global View to Collections

Museum databases are usually situated at different locations and use different database systems and schemas. This creates a severe obstacle to information retrieval. To address the problem, the web can be used for creating a single interface and access point through which a search query can be sent to distributed local databases and the results combined into a global hit list. This "multi-search" approach is widely applied and there are many cultural collection systems on the web based on it, such as the portals Australian Museums Online[6] and Artefacts Canada[7].

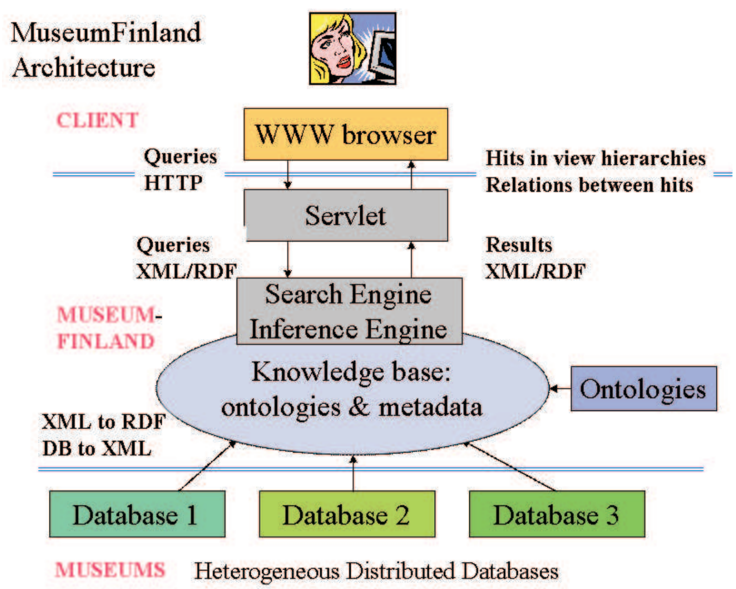


**Fig. 2.** Information retrieval in MuseumFinland. Local database contents are first merged and the query is evaluated with respect to the global interrelated data.

A problem of multi-search is that by processing the query independently at each *local database*, the *global* dependencies, associations between objects in different collections are difficult to found. Since exposing semantic associations between collections items is one of our main goals, MuseumFinland cannot be based on the multi-search paradigm. Instead, the local collections are first consolidated into a global repository, and the queries are answered based on it (cf. figure 2). Mutually shared conceptual models, ontologies, are used for enriching the content and for making the collections interoperable.

The challenge in consolidating the collections is how to make them interoperable in syntax and, especially, in semantics. In our solution [11], the museum first transforms its collection data into XML (cf. figure 3). Each collection object is represented as an *XML card* that describes the object in terms of 22 properties whose values are strings and numbers read from the underlying database. The XML Schema used is agreed upon by the participating museums and guarantees syntactic interoperability of the collections.

[6] http://amol.org.au/collection/collections_index.asp
[7] http://www.chin.gc.ca

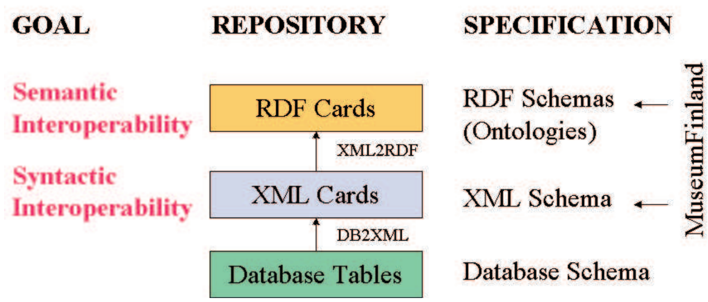


**Fig. 3.** Data transformations in MuseumFinland.

| Ontology | Content | Class | Inst. |
|---|---|---|---|
| **Artifacts** | Classes for tangible collection objects | 3227 | 0 |
| **Materials** | Substances that the artifacts are made of | 364 | 0 |
| **Situations** | Situations, events, and processes in the society | 992 | 0 |
| **Actors** | Persons, companies, organization, and other active agents | 26 | 1715 |
| **Locations** | Continents, countries, cities, villages, farms etc. | 33 | 864 |
| **Times** | Eras, centuries, etc. as time intervals | 57 | 0 |
| **Collections** | Museum collections included in the system | 22 | 24 |

**Table 1.** Ontologies in the MuseumFinland portal.

Next, each XML card is transformed into an *RDF card* with similar RDF properties, but where up to 16 string values are transformed into the URIs of the corresponding classes and individuals in a set of underlying RDF(S) ontologies. The seven ontologies used and their sizes in terms of classes and individuals are depicted in table 1. The XML to RDF transformation is based on a set of *term cards* that map terms (i.e., strings) used in collection databases with ontology resources. MuseumFinland provides the museums with the ontologies and a set of term cards. The museums can adapt their terminological conventions to the portal by creating new term cards of their own. Two special tools have been developed for creating terminologies (Terminator) and RDF annotations (Annomobile) semi-automatically. Protégé-2000[8] is used for the manual editing part.

Figure 4 illustrates the general term card extraction process in MuseumFinland. The process involves a local process at each participating museum and a global process at MuseumFinland. At the museum side, Terminator is used for extracting unknown terms used as values in the XML cards. A term is unknown if it does not have a term card relating it to the resources of the underlying ontologies (either to the general "MAO" ontologies Artifacts, Materials, and Situations, or to the Locations, Actors, or Collections ontology). A human editor is needed in the loop for giving the right interpretation (resource

[8] http://protege.stanford.edu/

reference) for the unknown terms. A term may have different cards with respect to different ontologies. The result of this process is a set of new term cards. This set is included in the museum's local terminology and terms of global interest can be included in the global terminology of the whole system for other museums to use.

The global terminology consists of terms that are used in all museums. It reduces the workload of individual museums, since these terms need not be included in local terminologies. The local term base is important because it makes it possible for individual museums to use and maintain their own terminologies.

When creating a new term card, it may occur that there is no appropriate concept in the ontologies that the new term can be associated with. In this case, the term is associated with a more general concept and a suggestion is made to MuseumFinland for extending the ontology later on with a more accurate concept.

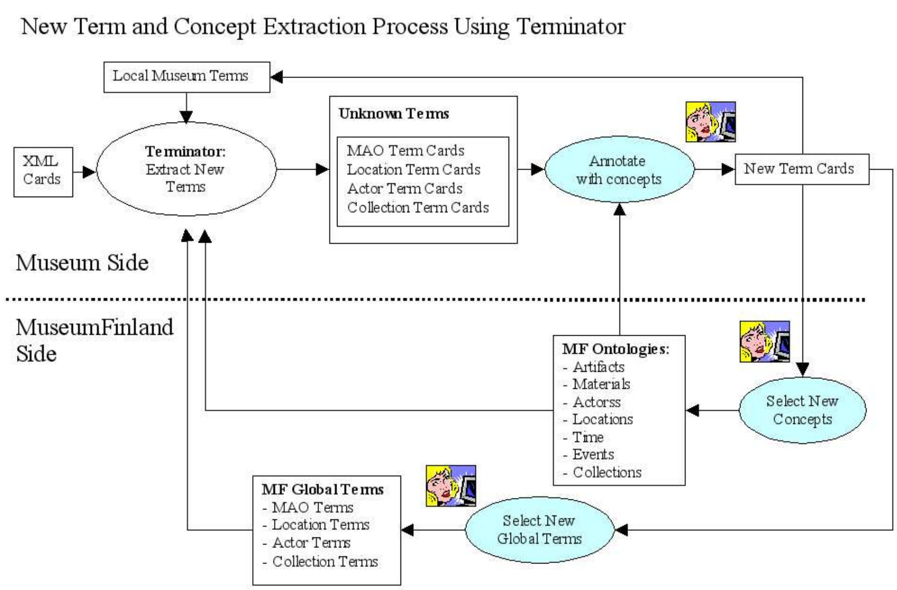


**Fig. 4.** Creating new term cards in MuseumFinland.

## 3 Content-Based Information Retrieval

The content-based search engine of MuseumFinland is a server called Ontogator. Ontogator is based on the multi-facet view-based search paradigm developed within the information retrieval research community [17, 6, 10]. Multi-facet

| View category | View | Ontology |
|---|---|---|
| **Object** | Artifact | Artifacts |
| | Material | Materials |
| **Creation** | Creator | Actors |
| | Location of creation | Locations |
| | Time of creation | Times |
| **Usage** | User | Actors |
| | Location of usage | Locations |
| | Situation of usage | Situations |
| **Museum** | Collection | Collections |

**Table 2.** View facets in the MuseumFinland portal.

search is based on a set of *categories* that are organized into a set hierarchical, orthogonal taxonomies called subject *facets* or *views*.

A search query in multi-facet search is formulated by selecting categories of interest from the different facets. For example, by selecting the category "Furniture" from the Artifact facet, and "Eero Saarinen" from the Creator facet, the user can express the query for retrieving all kinds of furniture, such as chairs, tables, etc., created by Eero Saarinen. Intuitively, the query is a conjunctive constraint over the facets with disjunctive constraints over the sub-categories in each facet.

More formally, if the categories selected are $C_1, ..., C_n$ and the subcategories of $C_i, i = 1...n$, including $C_i$ itself are $S_{i,1}, S_{i,2}..., S_{i,k}$, respectively, then this selection corresponds to the following boolean AND-OR-constraint:

$$(S_{1,1} \vee ... \vee S_{1,k}) \wedge (S_{2,1} \vee ... \vee S_{2,l}) \wedge ... \wedge (S_{n,1} \vee ... \vee S_{n,m}) \qquad (1)$$

Facets can be used for helping the user in information retrieval in many ways. Firstly, the facet hierarchies give the user an overview of what kind of information there is in the repository. Secondly, the hierarchies can guide the user in formulating the query in terms of appropriate keywords. Thirdly, the hierarchies can be used to disambiguate homonymous query terms. Fourthly, the facets can be used as a navigational aid when browsing the database content [6]. Fourthly, the number of hits in every category that can be selected next can be computed *beforehand* and be shown to the user [17]. In this way, the user can be hindered from making a selection leading to an empty result set—a recurring problem in IR systems—and is guided toward selections that are likely to constrain (or relax) the search appropriately.

Table 2 depicts the 9 views used in MuseumFinland and their underlying 7 ontologies. The Artifacts ontology is a taxonomy of the tangible collection objects such as pottery, cloths, weapons, etc. All exhibits in the system belong to some class in this ontology. The Materials ontology is a taxonomy of the artifact materials, such as steel, silk, tree, etc. The Actors ontology defines classes of agents, such as persons, companies etc., and individuals as instances of these classes. The Events ontology include intangible happenings, situations, events,


**Fig. 5.** The search interface of MuseumFinland.

and processes that take place in the society, such as farming, feasts, sports, war, etc. Locations is an ontology representing areas and places on the Earth and in Finland in particular. The Times ontology is a taxonomy of various predefined historical periods, and the Collections ontology classifies the museums and collections in the portal. The Artifacts, Materials, and Events ontologies are subsets of a larger cultural ontology called MAO (6768 classes) that we created based on the Finnish cultural thesaurus MASA [13].

Figure 5 shows the search interface of MuseumFinland. The nine facet hierarchies of table 1 are shown (in Finnish) on the left. For each facet hierarchy, the next level of sub-categories is shown as links. A query is formulated by selecting a sub-category by clicking on its name. When the user selects a category $c$ in a facet $f$, the system constrains the search by leaving in the result set only such objects that are annotated in facet $f$ with some sub-category of $c$. The figure depicts the situation after selecting the sub-category Tools ("työvälineet") from the Artifact facet ("Esinetyyppi"). The result set is shown on the right grouped by the sub-categories of Tools, such as Textile making tools ("tekstiilityövälineet") and Tools of folk medicine ("kansanlääkinnän työvälineet"). Hits in different categories are separated by horizontal bars and can be scrolled independently in each category. In this case, all categories do not fit in the screen shot.

When answering the query, the result set for each direct sub-category in the facets seen on the screen is recomputed, and a number ($n$) is shown to the user after the category name. It tells that if the sub-category is selected next, then there will be n hits in the result set. For example, the number 643 in the Collection facet on the bottom ("Kokoelma") tells that there are 643 tools in the collections of the National Museum ("Kansallismuseon kokoelmat"). A selection leading to an empty result set ($n$=0) is removed from its facet (or alternatively disabled and shown in gray color, depending on the user's preference). In this way, the user can be hindered from making a selection leading to an empty result set, and is guided toward selections that are likely to constrain the search appropriately. The query can be relaxed by making a new selection on a higher level of the facets or by dismissing the facet totally from the query.

In above, the category selection was made among the direct sub-categories listed in the facets. An alternative way is to click on the link Whole facet ("koko luokittelu") on a facet. The system then shows all possible selections in the facet with hit counts. In this way, the user can easily formulate the query using the right categories exposed to her as links, and can get easily overviews of the database contents along different classifications in different situations.

User studies [12, 4] indicate that if the user does not precisely know what (s)he is looking for, then the multi-facet search method with its "browsing the shelves" sensation is clearly preferred over keyword search (or using a single facet search). Otherwise, a direct Google-like keyword search interface is preferred. To support word-based search, too, an additional search engine was implemented in MuseumFinland (upper left corner in figure 5). This engine is used for two purposes at the same time: for searching categories to be used in multi-facet search and for searching collection objects with matching metadata values in the conventional way. [9]

## 4 Semantically Linked Contents

One of the main goals of the MuseumFinland portal is to reveal the rich semantic linkage connecting the collection objects with each other. The links can be *explicit* or *implicit*. Explicit links correspond to the RDF statements (triples) in the underlying knowledge base and are based on the collection domain ontologies (classes and their properties) and the actual collection data (instance data). For example, an instance of a painting may have the RDF property dc:creator linking the art work to an individual artist. Implicit links can be defined in terms of explicit ones but are not present in the RDF graph. For example, if there are explicit links linking children with their mothers and fathers, then implicit links such as "grandfather" or "cousin" can be defined.

In MuseumFinland, implicit links are defined declaratively in terms of logic by using Prolog predicates. Each predicate defines a semantic association and gives it an explanatory label, such as "cousin of". By applying such a predicate to a collection item resource, implicitly related other resources with respect to the semantic association can be found. On the HTML level in the user interface, the label of the association is used as the name for the link and the found resource as the target. For example, if the family relations of artists are known in the ontology, then such a predicate could infer links to other pages depicting paintings whose creator is of the same family.


**Fig. 6.** Collection item metadata with semantic recommendations.

For example, figure 6 depicts an collection object page found by multi-facet search. The object is a distaff ("rukinlapa" in Finnish) used in a spinning wheel. On the left, a photo of the object is shown. The metadata of the object is shown in the middle on top. All facet categories of the object are listed in the middle bottom as hierarchical link paths. A new search can be started by selecting any link from there. On the right, the system displays links to other recommended collection items. i.e., *semantic recommendations.*

The recommendation links provide a semantic browsing facility to the end-user. For example, in figure 6 there are links to objects used at the same location (categorized according to the name of the common location), to objects related to similar events (e.g., objects used in spinning, and decorative objects, because distaffs are usually beautifully decorated), to objects manufactured at the same time, and so on. Since a decoratively carved distaff used to be a typical wedding gift in Finland, it is also possible to recommend links to other objects used as wedding gifts, such as wedding rings. In MuseumFinland, such associations can be exposed to the end-user as link groups whose titles and link names explain to the user the reason for the recommendation. The possibilities for creating such associations are intriguing. Of course, only links that can be inferred based on the metadata and ontologies available can be created.

Recommendations are defined in terms of flexible logical predicate rules using the methods described in [8]. The semantic recommendation system of MuseumFinland is implemented as a logic server called Ontodella. This system is based on the HTTP server version of SWI-Prolog[9] [19].

## 5 Implementation and Mobile Usage

MuseumFinland as a whole was implemented by a semantic web portal tool OntoView [15] for publishing RDF content on the web. OntoView provides the portal designer with the content-based search engine server Ontogator and the link recommendation system server Ontodella. The user interface is created by combining these servers with the Apache Cocoon framework[10]. OntoView queries the Ontogator search engine server and Ontodella logic server with XML/RDF messages. It is possible to do this over HTTP. Cocoon pipelines and XSLT transformations from XML/RDF into XHTML are used for creating the user interface.

To test and demonstrate usability of OntoView, also a mobile telephone user interface to MuseumFinland has been created. It can be used with WAP 2.0 compatible mobile telephones. The mobile interface repeats all functionality of the PC interface, but in a layout more suitable to the limited screen space of mobile devices. The search results are shown first up front noting the current search parameters for easy reference and dismissal, as seen in figure 7. Below this, the actual search facets are shown. Figure 8 shows the facets as they appear in the mobile user interface. Here selectable sub-categories are not shown as explicit links as in the PC UI, but as drop-down lists that replace the whole view when selected. This minimizes screen space usage while browsing the facets, but maximizes usability when selecting sub-categories from them. In-page links are provided for quick navigation between search results and the search form.

The item page (corresponding to figure 6) is organized in a similar fashion, showing first the item name, images, metadata, annotations, semantic recommendations, and finally navigation in the search result. There are also in-page links for jumping quickly between them different parts of the page.

The mobile user interface also provides two distinct services aimed specifically for mobile use. Firstly, the interface supports search by the geolocation of the mobile device in the same manner as in the concept-based OntoView keyword search. Any entries in the Locations ontology near the current location of the mobile user are shown in a dynamic facet as well as all data objects made *or* used in any of these locations. In addition, any objects directly annotated with geocoordinates near the mobile user are shown grouped as normal. This feature gives the user a one-click path to items of likely immediate interest. Secondly, because extended navigation and search with mobile devices is tedious, any search state

[9] http://www.swi-prolog.org

[10] http://cocoon.apache.org/

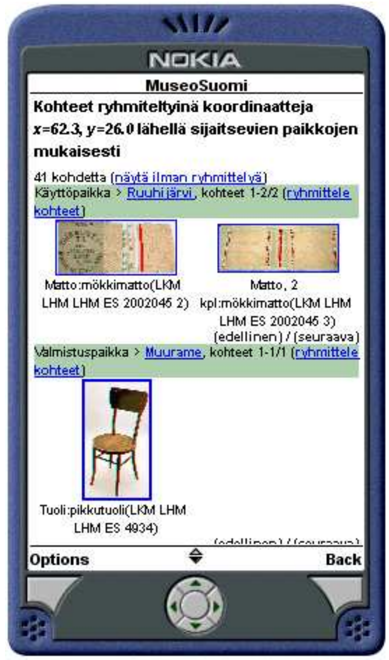


**Fig. 7.** Results of a mobile geolocation search initiated somewhere near Ruuhijärvi, Finland.

can be "bookmarked", sent by email to a desired address, and inspected later in more detail by using the more convenient PC interface.

# 6 Discussion

## 6.1 Contributions

MuseumFinland is an application of the idea of semantic portals to solving interoperability problems of museum collection databases when publishing their content on the Semantic Web. The power of MuseumFinland comes from the use of ontologies:

**Exact definitions** By using ontologies, the museums can define the concepts used in cataloging in a precise, machine understandable way.

**Terminological interoperability** The terms used in different institutions can be made mutually interoperable by mapping them onto common shared ontologies. The ontologies are not used as a norm for telling the museums what terms to use, but rather to make it possible to tolerate terminological variance as far as the terminology mapping from the local term conventions to the global ontology is provided.


**Fig. 8.** The search facets, including a dynamical location-facet creation after a geolocation search initiated somewhere near Ruuhijärvi, Finland.

**Ontology sharing** Ontologies provide means for making exact references to the external world. For example, in MuseumFinland, the location ontology (villages, cities, countries, etc.) and the actor ontology (persons, companies, etc.) is shared by the museums in order to make the right and interoperable references. For example, two persons who happen to have the same name should be disambiguated by different URIs, and a person whose name can be written in many ways, should be identified by a single URI to which the alternative terms refer.

**Automatic content enrichment** Ontological class definitions, rules, and consolidated metadata enrich collection data semantically.

**Intelligent services** Ontologies can be used as a basis for intelligent services to the end-user. In MuseumFinland, the view-based search engine is based on the underlying ontological structures and the semantic link recommendation systems reveals to the end-user the underlying semantical context of the collection items and their mutual relations.

The novelty of the content-based search engine with respect to other view-based systems [17, 6] is based on its capability of using RDF(S) ontologies as the basis of search. The main benefits obtained are: 1) Ontological logical inference can be employed in projecting the views from the ontologies (e.g., the location meronymy and various concept hyponymies). 2) The implicit complicated relations between view categories and the underlying data resources to be searched for can be specified flexibly in terms of logical predicates. Ontogator combines virtues of the view- and ontology-based search paradigms [10].

### 6.2 Related Work

The idea of linking collection items with semantic associations was inspired by Topic Maps [16]. However, in our case the links are not given by a map but are determined by logical inference using the underlying RDFS ontology and RDF metadata. Another application of this idea to generating semantically linked static HTML sites from RDF(S) repositories is presented in [8]. Logic and dynamic link creation on the semantic web has been discussed, e.g., in the work on Open Hypermedia [5, 3]. In the HyperMuseum [18], collection items are also semantically linked with each other. Here linking is based on shared words in the metadata and their linguistic relations, such as synonymy and antonymy. In contrast, our system is not based on words but on ontological references in the underlying RDF(S) knowledge base and the links can be defined freely in terms of logical rules. The idea of annotating cultural artifacts in terms of multiple ontologies has been explored, e.g., in [7]. The CIDOC Conceptual Reference Model (CRM) [2] is a high-level ontology-based standard proposal for representing cultural heritage data in a semantically interoperable way. MuseumFinland has the same goal but, in contrast, focuses on ontological representation of collection objects and their property values by detailed low-level ontologies.

### 6.3 Lessons Learned

The main problem encountered in the content work was that the original museum collection data in the databases was not systematically annotated. Various conventions are in use in different museum systems and museums. Much of the metadata is not based on keywords but is free text. The Terminator and Annomobile tools developed for the XML to RDF transformation [11] are only semi-automatic, and a human editor is often needed to make the right annotations. Due to homonymy, not even thesaurus keywords can always be mapped unambiguously to RDF concepts by the machine. However, the homonymy problem turned out to be less severe than expected, because disambiguation could be based on the facet/ontology to which the database field was related.

The view-based search method can be implemented quite efficiently. The current system scales up to the order of 10,000 RDF cards and 10,000 ontological concepts on an ordinary PC server. From the user's perspective, the idea of multi-facet search seems useful and a natural next step ahead from the single facet systems on the web today, such as Yahoo[11] and Open Directory Project[12]. Using Prolog and RDF together for projecting the facets and for creating the semantic

[11] www.yahoo.com
[12] www.dmox.org

recommendation links was powerful and flexible. It is possible to compute and store the results of some inferences before running the system in order to speed up reasoning. In our case, the mappings between facet categories and RDF resources are determined in Prolog beforehand and are compiled into an RDF tree that can be used more efficiently by the view-based search engine. The semantic recommendations are currently determined dynamically.

MUSEUMFINLAND user interface was first implemented as a Java servlet using XSLT transformations. The system was then re-designed and re-implemented using the Cocoon-based tool ONTOVIEW [15]. With Cocoon, the implementation could be made in a couple of months and can be modified easily. For example, the mobile telephone interface was created by modifying the PC version.

### 6.4 Further Work

We are investigating how new kind of RDF material, conforming to different ontologies, such as art collections using the Iconclass[13] system and educational videos based on the IEEE Learning Objects Metadata standard, can be merged in the portal. More work is needed in developing a set of recommendation predicates that would be of most interest to the users.

Ways of collaboration between museum content providers and portal maintenance people need to be developed in order to develop MUSEUMFINLAND from an application into a continuous publication *process*. For example, protocols for adding, modifying, and retracting RDF cards and ontology resources according to the wishes of the museums need to be developed.

The pilot version of MUSEUMFINLAND portal was opened on the public web in March 2004 at `http://museosuomi.cs.helsinki.fi`.

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