Ontology-based Approach for Interoperability of Digital Collections

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This paper presents solutions and lessons learned in FinnONTO project carried out in Finland in 2003–2007. The paper focuses on three aspects of interoperability of digital collections. First, transforming thesauri to ontologies. Second, publishing ontologies for the use of indexers and content providers. Third, ontology based methods for improving end user access to digital collections.

The first aspect is analysed through case studies done with Finnish thesauri. The second is discussed by presenting the ONKI ontology server. The last aspect is demonstrated in the scope of the semantic portal CultureSampo for publishing cultural heritrage on the Semantic Web.

Introduction

Digital libraries and memory organizations such as museums, libraries and archieves, are heading major challenges in the digital age. We are moving fast from preserving and cataloguing physical objects such as books or artifacts to archival of digital artifacts such as electronic copies of texts or images of the physical artifacts.

While the digitalized collections are available in growing numbers, accessing, indexing and searching these collections is far from trivial. A widely shared goal of cultural institutions and libraries is to provide the general public and the researchers with aggregated views to collections, where the users are able to access the contents of several heterogeneous distributed collections simultaneously.

A key success factor in enabling such aggregated views to the collections is interoperability. Interoperability generally refers to the ability of two or more systems or components to exchange information and to use the information that has been exchanged. Interoperability can occur at a syntactic or a semantic level. The basis for syntactic interoperability is sharing syntactic forms between different data sources, i.e., the metadata schemas such as the Dublin Core Metadata Element Set[1]. Such schemas make it possible to identify different aspects of the search objects, such as the “author”, “title”, and “subject” of a document.

Interoperability at the semantic level means that not only the form of the data is shared, but also the values used in the schemas are semantically defined. Syntactic interoperability enables simultaneous queries to multiple underlying knowledge bases.

However, a query like “objects where Paris appears as a subject matter” would only return results where the term “Paris” is mentioned. In other words, based on syntactic interoperability only, the objects that depict for example “Montmartre” are not returned because the computers are unable to determine that “Montmartre” is actually a “part-of”

[1] http://dublincore.org/documents/1998/09/dces/

"Paris" and therefore relevant to the query expressed. Supporting such queries requires semantic interoperability.

The National Semantic Web Ontology project

The National Semantic Web Ontology project (FinnONTO 2003-2007)[2] develops an infrastructure of tools and ontology-based methods to support semantic interoperability in various application fields on the Semantic Web[3] (Hyvönen et al., 2007a). The work includes the following goals and tasks:

1. *Transforming thesauri to ontologies.* The vocabularies used traditionally for content aggregation on a semantic level are thesauri. As thesauri are meant in first hand for human users, a lot of information on concept relations which computers need is missing or is not accurate enough. Ontologies also present the shared conceptualization captured in the thesauri, but are explicit and machine understandable.

2. *Publishing and using the ontologies.* Organizations need easy and cost-efficient support services for publishing ontologies and to ensure the availability and acceptance of the ontologies. In addition, the content indexers need methods to support indexing content using ontological concepts as metadata values in their own applications. Typically, the indexing is done using legacy systems which may be difficult and expensive to update to support ontologies and more detailed metadata.

3. *Semantic search, recommendation, and visualization methods for end users.* To provide the content searchers with ontologically enhanced search functionalities, new methods are required to benefit from the rich semantic indexing that ontologies and semantic metadata enable.

This paper discusses the realization of these goals and tasks in practice, especially from the viewpoint of semantic interoperability of digital collections. The rest of the paper is structured as follows. First, practices and principles to transform thesauri into ontologies and into a system of interlinked ontologies are presented (Hyvönen et al., 2008). Second, solutions to publish and efficiently use ontologies in indexing are presented (Viljanen et al., 2008; Hyvönen et al., 2008).

Finally, the use of the rich metadata and ontologies are discussed in scope of an end user application, the semantic portal *CultureSampo*[4] (Hyvönen et al., 2007b; Ruotsalo and Hyvönen, 2007ab):

http://www.kulttuurisampo.fi/

[2] http://www.seco.tkk.fi/projects/finnonto/

[3] http://www.w3.org/2001/sw/

[4] Project home page: http://www.seco.tkk.fi/applications/kulttuurisampo/

The paper focuses on overviewing the ideas underlying our work. Technical descriptions, as well as discussions of related research, can be found in more detail in the references.

Transforming Thesauri to Ontologies

A major source to enable semantic interoperability are thesauri that conceptualize the domain under interest. For example, a geographical thesaurus could state that "Montmartre" is a "part-of" "Paris" and therefore this information could be used to expand the query. Because thesauri are meant for human users the structure of the thesauri has not been designed with semantic reasoning in mind. Therefore, a direct transformation from thesauri to ontology confronts several problems.

To address these problems in FinnONTO, the General Finnish Ontology YSO[5] was created. It is based on the Finnish General Thesaurus YSA[6] (maintained by the National Library of Finland) which contains some 26,000 concepts. Several special Finnish thesauri that intersect with YSA exist and are therefore often used together with the general thesaurus. The requirement of the project was also not only to transform these special thesauri into ontologies, but also to align the interrelated ontologies. The building of the General Finnish Ontology YSO and alignments to special ontologies included five phases:

1. *Syntactic conversion.* Thesauri are maintained in various formats, for example XML[7], databases or in text files. This means that even if tools are available for converting data into SKOS (Simple Knowledge Organisation System), RDF[8] (Resource Decsiption Framework) and OWL[9] (Web Ontology Language)[10] which are used in presenting ontologies, in many cases tailor made tools are needed because some of the formats are unique for a certain thesauri. The building of the General Finnish Ontology YSO was started by converting the Finnish General Thesaurus from Marc XML[11] into OWL and SKOS format.

2. *Definition of upper ontology.* Typically a thesaurus consist of only small concept groups which are not hierarchically connected to each other, because of missing subclass-of relations. For example, in the Finnish General Thesaurus a large number of concepts like "habitus", "attitude", and "sunspots" are presented without a superordinate concept. This is why there is no hierarchy a computer could use for reasoning unless the missing relations are added.

[5] http://www.yso.fi/onto/yso/

[6] http://vesa.lib.helsinki.fi/

[7] http://www.w3.org/XML/

[8] http:// www.w3.org/RDF/

[9] http://www.w3.org/2004/OWL/

[10] http://www.w3.org/2004/02/skos/

[11] http://www.loc.gov/standards/marcxml/

An upper ontology was created for the ontology in order to combine the small concept groups of the thesaurus into one coherent hierarchy. The upper hierarchy of YSO is based on the ideas of DOLCE ontology (Gangemi et al., 2002).

3. *Ambiguity of relations.* Thesauri typically do not differentiate meanings of broader-term relations. Specifying subclass-of, part-of and instance-of relations further would enhance reasoning in end-use applications. For example, concept “faculties” has a broader term “universities” or concept “drawers” can have a broader term “artists”. However, because technical drawers are not artists and faculties are not a kind of universities the meanings have to be specified.

4. *Re-organising concepts.* The relations were specified for each broader term hierarchy. In addition in thesauri cases occur where no relations are defined for a concept. In these cases the concepts are placed in hierarchy that corresponds to the intended semantic meaning of the concept. This enables transitive reasoning using concept hierarchies.

5. *Ambiguity of concepts.* Ambiguity means a concept having multiple or uncertain meaning. Polysemes and homonymes form a problem if they are left ambiguous. Without additional information on concept relations it is not possible to know, if for example the word “net” refers to a net as a technical system or to, for example, a tennis net, or if the term “parchment” refers to skin for writing on or to paper made to resemble the parchment made of skin.

   In cases of ambiguity the concepts a term can refer to were differentiated from each other by separating different meanings or creating new concepts for meanings that were missing in the original thesauri. After the meaning separation, each concept was placed to an appropriate place in the hierarchy, e.g. models (concrete object), for example a miniature model, and models (role), for example a person displaying clothes.

6. *Alignment of ontologies.* A closer examination of the general and special thesauri (for example, MASA thesaurus for cultural heritage and Agriforst thesaurus for agriculture and forestry) revealed that depending on the case 30%-70 % of the terms in domain specific thesauri are the same as in the general thesaurus. However it is not always clear if the terms really refer to the same concepts in both cases. There might also be different synonyms referring to the same concept in different thesauri (for example environmentally friendly products - environment-friendly products).

   These discrepancies have to be cleared so that the thesauri can be effectively used. The task was carried out semi-automatically. The term strings of two ontologies were first compared and if match was found, the terms were marked as equivalents by the computer. In addition to the preferred terms also non-preferred terms and equivalents in different languages can be used when making the comparison. After this the potentially equivalent concepts were checked by human and other concepts arranged according to the upper hierarchy created for YSO.

The work on General Finnish Ontology YSO started in 2004 and is being continued in a follow up research project FinnONTO 2.0 (Semantic Web 2.0). In different phases of the project, 1-10 persons participated in the ontology transformation. During the work, almost 1,000 concepts were added to the ontology and the number of subclass-of relations increased by nearly 6,000. Through alignment of several special ontologies, over 6,000 new concepts were linked to the hierarchy of the general ontology, and new ontologies are being integrated in the system.

Publishing and Using the Ontologies

Producing ontologies that meet the requirements of explicit representation and machine understandability enable enhanced semantic interoperability. However, producing semantic metadata that indexes objects using the ontologies can be a tedious process.

To support the semantic metadata creation process *ONKI* Ontology Server was developed (Viljanen et al., 2008; Hyvönen et al., 2008). It is a general ontology library and framework that provides functionalities for publishing and accessing a library of ontologies. *ONKI* provides both user interfaces and application interfaces (for machines) for performing, e.g., content indexing, concept disambiguation, searching and fetching:

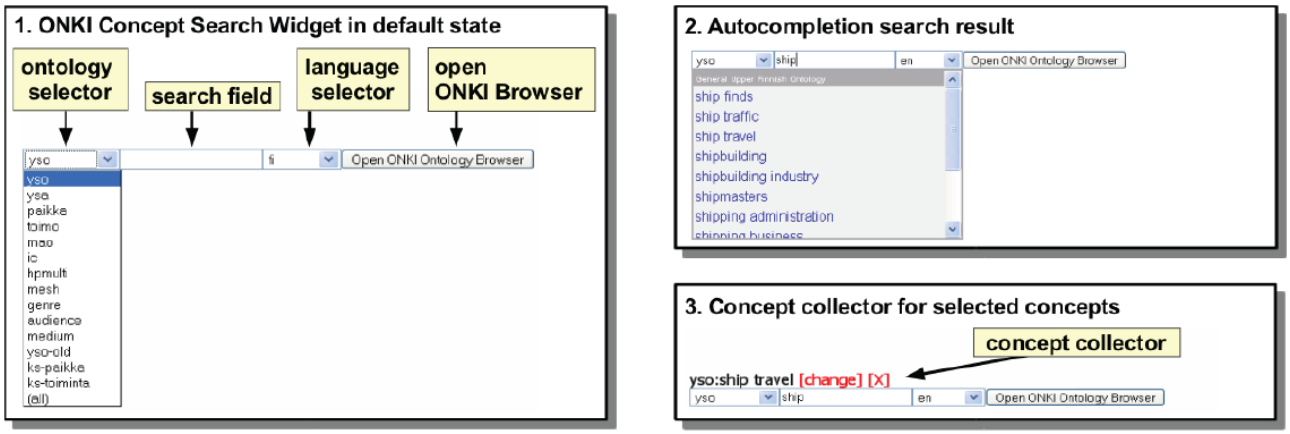

Figure 1: ONKI Indexer interface and autocompletion interface

1. *Indexer interface. Figure 1* presents the indexer's main user interface – the *ONKI* Widget – which enables the user to first find the correct ontological concepts and their identifiers, and second transfer these identifiers and related concept labels to the user's own content management application such as a cataloguing system of a library. The idea is that ordinary text fields of existing content indexing applications can be easily replaced with enhanced ontological concept search fields as depicted in the figure. When this minor modification has been done, the updated system can be used for creating ontological metadata and thus enabling semantic applications for publishing, finding and accessing digital collections.

2. *Autocompletion interface.* Part 2 of the Figure 1 shows the *ONKI* autocompletion interface. This enables dynamic search to fetch concepts starting with a user defined prefix. The *autocompletion search field* dynamically performs a query after

each input character (here “s-h-i-p-...”) and returns the matching concepts of the target ontology.

In the case of synonym terms, the preferred label of a concept will be presented. For example, when searching for an (outdated) term “birch sugar”, the system returns “birch sugar → xylitol” which means that “xylitol” is the preferred term. By clicking on a concept, its identifier and label are stored in the *concept collector* for further usage, such as saving it to a database. The idea of the concept collector can be compared to the idea of shopping carts in web stores.

3. *Browsing interface.* If the user does not know what to type in the text search field, the alternative of using a browsing interface is available. Two domain-specific *ONKI* Browsers have been implemented during the FinnONTO project: *ONKI*-SKOS (Viljanen et. al., 2008) is intended for lightweight ontologies and thesauri (Figure 2) and *ONKI*-Geo (Kauppinen et. al. 2008) is designed for geographical ontologies including a geographical map interface for geo ontologies (Figure 3). Currently under development is the ONKI People ontology server for persons and organisations, which will be published soon.

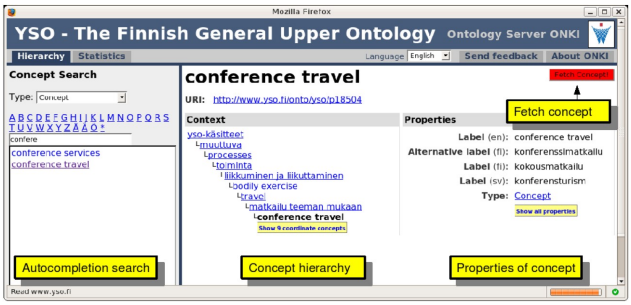

Figure 2: ONKI-SKOS Browser

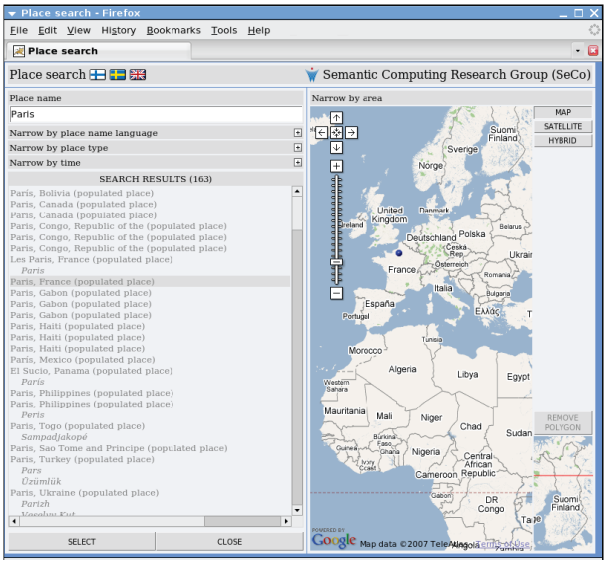

Figure 3: ONKI-Geo Browser

Indexing of digital collection objects often requires several ontologies to be used within a single indexing task. For example, general indexing terms such as “ship” or “boat” are required to index subject matters of the objects while geographical terms such as “Finland” or “Helsinki” are required for manufacturing place indexing.

To make such a hybrid use as easy as possible, a pilot version of the National Finnish Ontology Service was established[12]. It is the specific national location on the web where the latest and most relevant ontologies can always be found (Figure 4). Currently[13], the

[12] http://wwww.yso.fi/

[13] For the latest list of ontologies, please visit http://www.yso.fi

pilot service contains ca. 20 ontologies, such as the General Finnish Thesaurus YSA (with general Finnish terms, widely used e.g. in Finnish libraries), the Finnish General Upper Ontology YSO (based on YSA), the Finnish Geo-Ontology SUO (with over 800.000 Finnish locations), the Agriforest Ontology AFO, Kaunokki Thesauri (for literature), Ontology for Museum Domain MAO, Ontology for Applied Arts TAO, and many more.

The Ontology Service is currently provided as a pilot service as a part of the FinnONTO 2.0 project (2008-2009)[14], running as a Living Lab service in close co-operation with co-operating organisations to improve the service based on real-world feedback of the feasibility of the proposed solutions. The pilot service is open to all interested organisations and individuals who want to view the already published ontologies and, for example, by integrating them to their own applications using the *ONKI* Widget approach. The ultimate goal is to create a permanent national ontology service which would start when the pilot phase ends in year 2009. This would replace e.g. the National Library of Finland's VESA web thesaurus service[15].

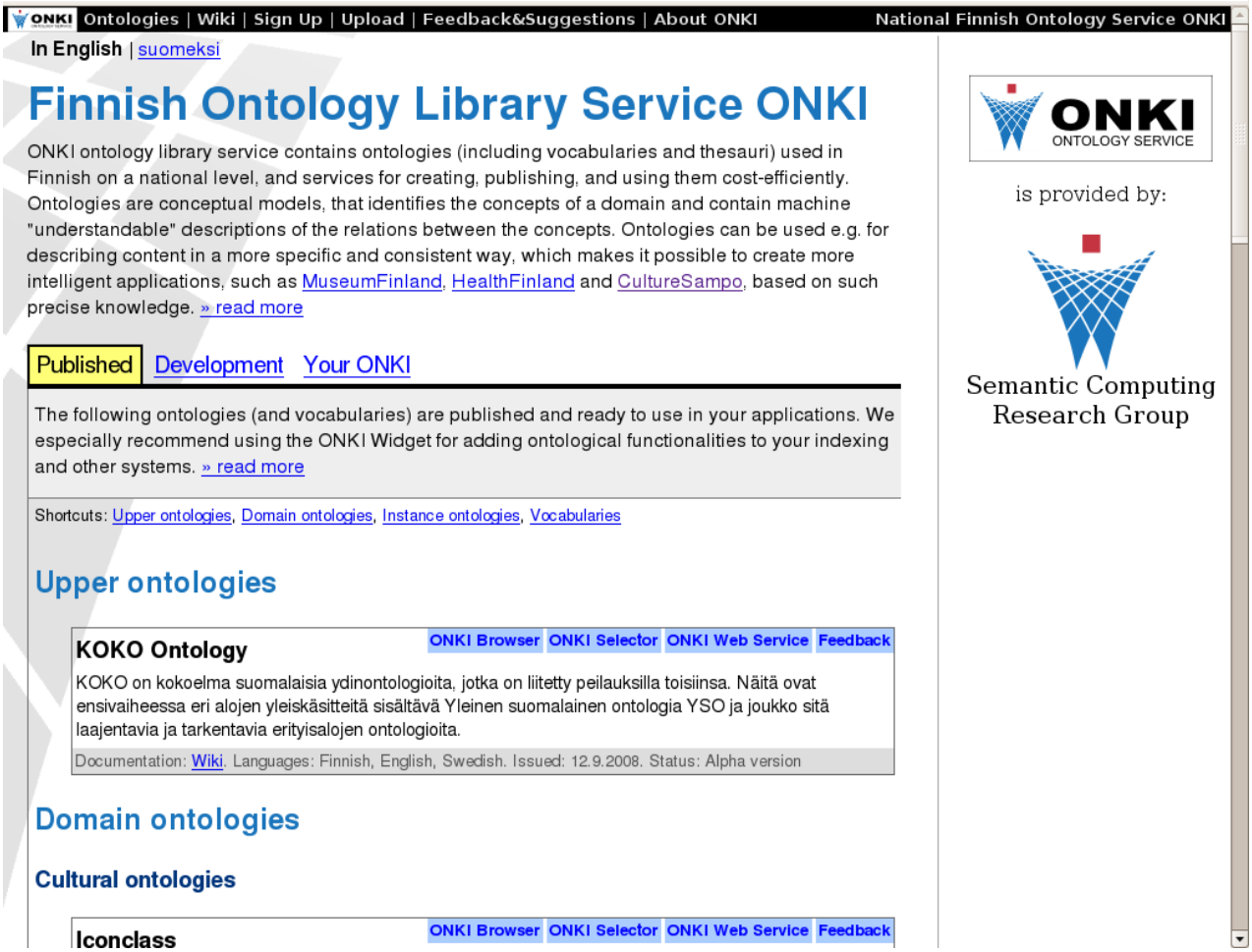

Figure 4: National Finnish Ontology Service http://www.yso.fi/

[14] http://www.seco.tkk.fi/projects/sw20/

[15] http://vesa.lib.helsinki.fi/

End User Applications

Ontologies provide a backbone for intelligent indexing and reasoning about the semantic metadata available as a result of the indexing task. However, ontologies and metadata are only valuable within a usage scenario such as information retrieval or automatic linking of objects. A major application area of the FinnONTO project is cultural heritage where data from heterogeneous collections are semantically enriched and methods for centralized access were developed.

The focus of the work was to study how to provide the end-user with intelligent search and browsing services based on semantically rich cross-domain content originating from different kind of cultural institutions. Three major methods were developed and implemented in semantic portal *CultureSampo* (Hyvönen et. al., 2007; Ruotsalo and Hyvönen, 2007ab):

Figure 5. Recommendation System of the CultureSampo portal.

1. *Semantic search. CultureSampo* portal facilitates semantic search (Mäkelä et. al., 2007). First, as faceted search where ontological structure can be used to limit the

search. Second, as semantic categorization or clustering of either faceted or keyword based search. For example, if a user uses keyword search to retrieve information about “Gallen-Kallela” the system is able to cluster the results as “textual documents about Gallen-Kallela”, “paintings painted by Gallen-Kallela” and “Persons that worked with Gallen-Kallela”.

On the other hand, the system is able to make use of rich background knowledge available in form of ontologies. For example, given query “furniture”, the system is able to return objects annotated as chairs or tables.

2. *Semantic recommendation system.* Semantic browsing or recommendation provides the users with related objects, when a certain object is under investigation (Ruotsalo and Hyvönen, 2007a). For example, Figure 5 shows an web-page illustrating a biography of Finnish artist Akseli Gallen-Kallela. The recommendation system is able to provide ranked links to the related resources, for example paintings painted by Gallen-Kallela. The system is also able to explain why the objects are related.

3. *Event-based knowledge representation. CultureSampo* portal makes use of advanced knowledge representation methods. The particular focus is in event-based knowledge representation that enables semantically richer annotations (Ruotsalo and Hyvönen, 2007b). Event-based annotations have been studied before, e.g., in the context of annotating the subject of photographs (Schreiber et al., 2001) and in representing narratives (Zarri, 1988). To illustrate the idea, consider the recommender system in figure 5.

   In the topmost item on the right side of the screen the system provides information about the painting being related to “rewarding of a painting called Aino Triptych”, “painting of Aino-Triptych” and being “Painted by Akseli Gallen-Kallela”. In this way the actual events (rewarding, painting and result and agent of the painting) annotated in the biography document can be related to the metadata of objects in other collections, such as paintings from Finnish National Gallery and author listings such as ULAN of Getty Foundation[16].

Search and recommendation methods in CultureSampo are able to utilize event-based knowledge representations. Event-based knowledge representation has three advantages (Ruotsalo and Hyvönen, 2007b).

First, implicit event knowledge embedded in metadata schemas can be explicated. For example, based on the metadata of a painting with “Akseli Gallen-Kallela” as “creator” and “1888” as a “manufacturingTime”, the computer is unable to relate the object to “painting” as an event that took place in “1888”, where “Gallen-Kallela” is an agent.

[16] http://www.getty.edu/research/conducting_research/vocabularies/ulan/

Kullervon sotaanlähtö A III 2144

P129F_is_about:
KALEVALA, KOHTAUS, Kullervo, tuohitorvi
miekka, ornamentti, ELÄIN, hevonen
koira, MAISEMA, talvi, taivas, tähdet, lumi

Figure 6. Metadata for image of "Kullervo departs for the war" (the Finnish National Gallery)

Second, the explication of missing role knowledge is possible. For example, consider an annotation of a painting "Kullervo departs for the war" shown in Figure 6. The subject of content is here annotated by a set of keywords (in Finnish) including "Kullervo", "horse" and "dog". A problem from the knowledge representation viewpoint is that the mutual relations of the subject annotations are not known. For example, it is not known whether Kullervo rides a horse, a dog, both of them, or none of them. It is also possible that the dog rides Kullervo, and so on. Events can be used for elaborating the description, if needed, by specifying values for their thematic roles. In this case, for example, Kullervo would be in the "agent" role and the horse in the "patient" role in a riding event. This kind of information can be essential when searching the contents (e.g. to distinguish between riders and riding entities) or when providing the end-user with semantic links and explanations (e.g. to distinguish links to other riding paintings in contrast to other horse paintings).

Third, harmonized representation of the annotations is enabled. When using multiple heterogeneous metadata schemas, the number of reasoning rules explodes if a different set of rules has to be specified for each schema separately. For example, the fact that a person is born somewhere at a certain time may be represented in metadata schemas in numerous ways, say with properties "placeOfBirth" and "timeOfBirth", or with a "birth" event with the properties "time" and "place". Harmonization of these representations enables simpler reasoning procedures that are independent of the metadata schemas used.

Discussion

The FinnONTO project carried out in Finland in 2003–2007, 2008-2010 has focused on three aspects of interoperability of digital collections: transforming thesauri to ontologies, publishing ontologies for the use of indexers and content providers, and developing ontology based methods for improving end user access to digital collections. In this paper we have presented three solutions and applications to enhance the interoperability in practical applications: YSO general Finnish thesauri, *ONKI* ontology server and semantic portal *CultureSampo*.

A major source to enable semantic interoperability are thesauri that conceptualize the domain under interest. However, thesauri are meant for human users the structure of the thesauri has not been designed semantic interoperability in mind. To overcome this problem, YSO ontology was developed together with a method to transform thesauri into to a set of interlinked ontologies.

The *ONKI* Server provides a simple means for finding the correct concepts and fetching them to the user's application which are crucial issues to be solved for enabling ontological metadata creation and – ultimately – for enabling new applications based on the ontological additional knowledge, not available before. The National Finnish Ontology Service (*www.yso.fi*) provides the access point to the latest and most relevant ontologies for Finnish usage.

Ontologies are not useful without a usage context such as information retrieval. Using thesauri structures without further structuring, for example, in automatic linking of resources may lead to unsatisfactory results in the end user applications. This is why methods for information retrieval are required to realize the full vision of ontology-based systems. The semantic portal *CultureSampo* combines event-based knowledge representation with ontology-based retrieval and recommendation methods. FinnONTO ontologies, ONKI ontology services and *CultureSampo* portal will be maintained in a living lab environment for organizations to use in a national follow-up project of FinnONTO, FinnONTO 2.0 (2008-2009).

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[18] http://www.smartmuseum.eu/

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