Semantic Navigation through Multiple Topic Ontologies

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Abstract. A general problem to support semantic navigation is the definition of the effective presentation of knowledge and the definition of interaction patterns. One of the main challenges of Semantic Web is to understand how to exploit, in terms of visualization, the representation of knowledge classified in documents according to user needs. In this paper, we discuss on the use of a framework of multiple and distinct ontologies to support modelling, integration and visualization of personalized knowledge. The framework is at the base of an application aimed at the management and discovery of knowledge for communities of interest. In particular, we propose an approach to make multiple topic ontologies to support the semantic navigation available to users, exploiting semantic relations as explicit links among concepts, to define and reason on the specific context of working tasks.

1 Introduction

A general problem to support semantic navigation is the definition of the effective presentation of knowledge and the definition of interaction patterns. Users demand contents already classified and referenced with a presentation of the contents in a human-readable format and in a personalized framework.

The Semantic Web [1] already offers tools and languages to format, represent and make knowledge machine-processable. Some tools have been deployed to enable semantic access to heterogeneous resources. Some standards have already been proposed and accepted, at least in the language realm with Web Ontology Language (OWL) [2] and similar XML-based languages. Though, there is still the need to understand how knowledge, that is actually scattered on several ontologies on the Web, may be used, shared and visualized. But a very large effort has to be made to define specific semantic browsing functions.

One reason underlying the Web's success is the fact that HTML-based content is extremely easy to navigate. In contrast, the Resource Description Framework (RDF) [3], the corresponding standard language for the Semantic Web, does not provide simple features for content visualization and navigation.

Moreover, toolkits for generating, processing, and visualizing graphs of RDF data are widely available on most platforms [4]. Tools for editing data according to specific ontologies, such as Protégé, give knowledge engineers powerful tools for creating and manipulating data that corresponds to specific schema [5]. Other tools enable users to read, understand and query ontologies represented in a human readable fashion, these tools are typically inference engines like Racer [6] or Fact [7].

The ontology editors mainly provide users with little smart functions in terms of visualization and navigation of knowledge. For example, Protégé provides many plug-ins to visualize the ontology structures [8], but most of them display in the graph visualizations only the *is-a* relations, while other kinds of relations are implicitly computed.

Our approach aims to exploit these latter relations to navigate the knowledge described by ontology structures, and to define a set of interactions to really use ontologies as supporting tools in our daily work. In particular, we value the benefits ontologies may offer with regard to the creation and the presentation of new knowledge, mainly within dynamic and distributed environments that refer to multiple and distinct ontologies [35]. These ontologies are considered as particular views on a domain of a community of interest, especially within an organization or a social context that share the same information system. So for example, an ontology may deal with organizational aspects to let managers classify the work done by employees and another ontology may capture the domain aspects (i.e., the content) to let the workers classify the artifacts they produce.

Another aspect to be considered is the distributed nature of ontologies: it has been proved by many failures that a centralized ontology management is not a solution since people need to create their own views; instead, a distributed approach to creation, use and maintenance of multiple ontologies, even within a single information system, allows for richer representation of knowledge and maintenance of multiple views. Therefore, to achieve coherent and complete views, integration processes are needed. Integration mechanisms and processes to set up semantic mappings among ontologies are still open issues [24], even if several proposals have already been made [34].

In this paper, we propose an approach of de-centralized ontologies of different domains called *topic ontologies* to model the knowledge of a certain organization. We intend a topic ontology as a local agreement of a community coherently covering the semantic of a single topic. We describe also a mechanism of ontology integration through semantic relations to define semantic mappings among different ontologies. These ontologies are modular to support a large amount of concepts and relations, and a more efficient reasoning on the domain.

The framework of *topic ontologies* proposed in this paper has been tested with the information systems developed in two different projects: the IST project MILK (Multimedia Interaction for Learning and Knowing) [13][14][15] and the Italian FIRB project MAIS (Multichannel Adaptive Information Systems)[1] [16]. In both systems,

[1] http://www.mais-project.it/

the topic ontologies support users in semantic navigation and in a personalized description of a domain from different points of view, maintaining the heterogeneity of different resources.

The paper is organized as follows. Section 2 gives a topic ontologies definition and how we used them to model MILK project knowledge. Section 3 defines and discusses the integration and the mapping techniques of topic ontologies. Section 4 offers some examples of semantic browsing functions and section 5 demonstrates the use of the framework to support Web services design in an alternative case, related to the MAIS project. In section 6 related works are discussed. Finally, in section 7 some conclusions are provided.

2 Modelling by Topic Ontologies

The issue of organizing knowledge in multiple ontologies has been widely discussed in literature [9][10]. The de-centralized nature of the Web makes communities able to use their own ontologies to classify and reason on data. In this vision, ontologies are distributed and hence a key point becomes the mediation between distributed data using mappings between ontologies. In the domain of information systems, some integration systems and approaches (e.g., CUPID [11], MOMIS [12]) are "centralized" systems of mediation between users and distributed data sources, that is, they exploit mappings between a single mediated schema and schemas of data sources. Those mappings are typically modeled as views which are expressed using languages having a formal semantics. The "centralized" approach of mediation is probably not flexible enough, and distributed systems of mediation are more appropriate. However, the idea of correctness of the distributed systems is almost consolidated in the Semantic Web community.

We propose an approach of de-centralized ontologies of different domains called *topic ontologies* to model the knowledge of a certain organization. A topic ontology is a local agreement of a community coherently covering the semantics of a single topic. For example, topic ontologies cover technological, organizational, environmental aspects and the traditional content of a division of an organization. The use of topic ontologies enables a modelling task of bodies of knowledge starting from an approach of taxonomic conceptualization (i.e. through the relation of subsumption). The integration of many topic ontologies saving their specificity is one of our fundamental goals, to acquire interoperability and flexibility. In our experiments, a topic ontology is related and integrated to others through the explicit definition of semantic relations linking concepts according with the conceptualization shared in a community. As conceptualization we intend the formal structure of reality as perceived and organized by a community.

To maintain a de-centralized approach we have defined a framework of distributed ontologies. Key points of the framework are a uniform representation of semantics of data to easily understand them, a set of meaningful associations between the data, and third, an explicit formalization required to facilitate reasoning on data and deriving new knowledge. Finally, the uniform representation can support the integration of data that may be heterogeneous.

We applied the framework to the knowledge management system developed in MILK. One of the main users of the project is an Italian consultancy company performing knowledge intensive activities. The company's approach to consultancy is based on working in partnership with the client in order to build a “tailor made” solution to their organization and needs. A great part of company’s activities concerns social practices and knowledge management issues. Moreover, because the company’s nature is project based, employees usually work on different projects with different customers located in different sites. Therefore, each project gives rise to a specific, in-depth understanding of the client’s interests and work processes. Another aspect to consider in this kind of company is that one of the more natural exchanges of knowledge is around topics and people’s interests instead than organizational structures. So, the concept of community of interest is introduced, as a complementary and transversal view of knowledge. Furthermore, communities reflect the interests and/or expertise of people that are free to join one or more communities.

To facilitate knowledge sharing among different project teams, in MILK all the people, projects, documents and communities involved are represented as objects, including all the relations which exist between the different objects. The knowledge related to the company is organized in a group of elements annotated with a common set of metadata. Then these descriptions of elements are semantically enhanced by domain ontologies, to give a more effective support to users in classifying and discovering knowledge.

In particular, the ontologies of this company range over many topics (e.g., company organization, people profiles and interests, content of the projects, etc.). Some ontologies has been built from scratch especially those concerning specific contents of company (e.g., KM, CRM). Instead, those ontologies describing metadata related to social aspects and people profiles are based on public and popular ontologies as Dublin Core[2], FOAF[3] and available thesauri.

We have also reused a number of domain ontologies published on the Web; some examples of such ontology libraries include DAML Ontology Library[4], the Semantic Web Ontologies[5], and the Protégé OWL ontologies[6].

The adoption of OWL language, and the Protégé editor[7] as development tool for ontologies, allows us to reuse published ontologies into our framework. OWL is an expressive language for ontology representation and Protégé is a widely diffused ontology editor and it provides a knowledge modelling platform with support from a community of thousands of users.

To facilitate the use of the ontologies we must introduce a tool for ontology management and semantic navigation based on Protégé and Java called OMEC (Ontology Manager and Element Classifier). OMEC is an independent module integrated with the knowledge engine and the interaction module of MILK. This module provides a set of services to visualize the ontology structures, and the integrated ontologies via the explicit and the inferred semantic relations. The basic

2 http://dublincore.org/
3 http://www.foaf-project.org/
4 http://www.daml.org/ontologies/
5 http://www.schemaweb.info
6 http://protege.stanford.edu/plugins/owl/owl-library/
7 http://protege.stanford.edu/index.html

feature of the tool is to support the definition of terms, of their relationships and some capability to navigate and retrieve knowledge in ontology. Navigation is supported by a set of functionalities that include finding if and where a term is located in ontology, retrieve term definitions, retrieve relationships, getting the whole ontology tree, collecting statistics on use, such as number of times terms have been referenced and so on.

Once a preliminary set of ontologies has been built we started to define the associations between the ontology concepts and the elements described, to have a picture of the relations linking the different parts of our domain. For this reason, we made the internal relations existing between basic elements of domain explicit, explained by the domain experts.

Concepts are structured according to the semantic relations of subsumption (also called *is-a* or *class-inclusion*). The *is-a* relation [18] is implicit in the taxonomy structure, while the *part-of* relation [19] is simply used to express object compositions (aggregation). Properties and relations of concepts are inherited by subconcepts. Relations in an ontology are (by definition) not restricted to subsumption, we defined some kinds of semantic relations in the specific domains of our interest, and we investigated in the literature [20][21][22][23] some approaches on semantic relations to model ontologies. In ontology terms, these last relations are the user-defined properties (the object properties in OWL), e.g., *writes* can be a property of the concept *Author*, connecting to the concept *Book*. Moreover, in OWL it is possible to define a structure of sub-relations, for example *writes* is a sub-relation of *creates*.

For example, if we make the relations linking the metadata of different elements explicit, we obtain a path of concepts across different ontologies. Let us consider a simple scenario: an employ has to edit a contract, that is, he searches a document useful to complete this task. In a conceptual view, what follows is the path defining the links between the entities involved in such a scenario: *Contract → isA → Document → has → Author → isA → Person → has → Role → isInsertedIn → HRDepartment → partOf → Organization*.

The path can be also represented by a graph (Fig.1) in which the node *Contract* is in the centre of an ideal circle of concepts related between them (e.g., *Industry*, *Client*, etc.). In this case we have topic ontologies describing through taxonomies (symbolized by a tree icon) some concepts like *Document*, *Person*, and *Organization.* In the case of MILK, all of them have been developed specifically for the framework, created from scratch or based on available ontologies (FOAF for the *Person* ontology, UNSPSC[8] for the *Product* and *Industry* entities, DC for generic metadada, etc.). Moreover, each element stored in the system corresponds to an instance of these paths. In the next paragraph we will explain our methodology to integrate topic ontologies.

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[8] http://www.unspsc.org/

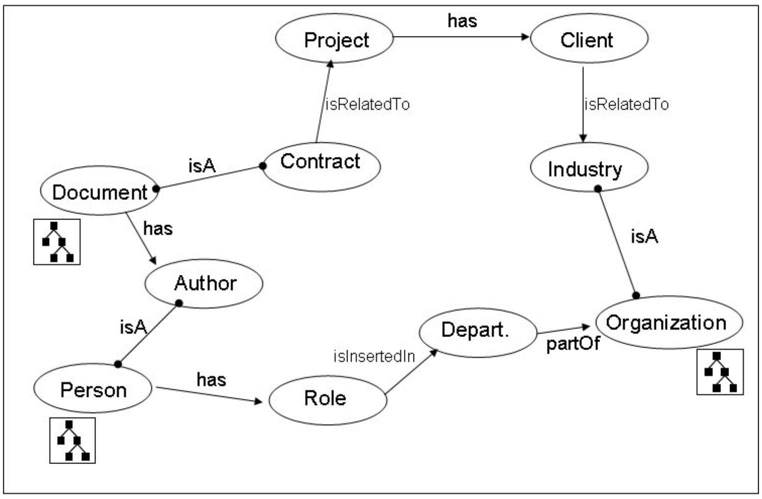

Fig.1 An example of graph representing the related concepts from different topic ontologies

3 Integration of Topic Ontologies

The theme of ontology integration and interoperability is strongly related to semantic navigation. In particular, by "integration" we mean the possibility to use a number of ontologies that describe the same domain from different points of view in an integrated way (for instance, an organizational domain ontology, and a spatial and/or temporal ontology). By "interoperability" we mean the possibility to create logical relations among concepts belonging to different ontologies maintaining the heterogeneity of different sources.

Hence, integration is proposed as a tool to map topic ontologies into a coherent framework. The integration of ontologies of different topics (e.g. content, organization, context etc.) consists in relating the concepts by semantic relations as bridges. The integration of ontologies of the same topic consists in a conceptual merge of similar concepts.

An ontology mapping process, as defined in [25], is the set of activities required to transform instances of a source ontology into instances of a target ontology. By studying the process and analyzing different approaches from the literature we observed a set of phases and assembled them into the framework. There are five basic phases: 1) normalization 2) capturing the similarity 3) semantic bridging 4) reasoning on context and 5) evolution and building consensus by the communities.

The normalization and the similarity phases focus on raising all data to be mapped onto the same representation level, coping with syntactical, structural and language heterogeneity. The ontologies must be normalized to a uniform representation, in our case OWL, eliminating syntax differences and making semantic differences between the source and the target ontology more apparent. In particular, for the similarity there are several different mechanisms in literature, we adopted a strategy focusing on acquiring a lexical similarity between each entity in source ontology with each in target ontology. For that we used suitable linguistic tools like WordNet[9].

Before passing to the next phase a survey of the possible relevant combinations to compare concepts and relations needs to be built, the aim is to identify which entities extracted from two ontologies become semantic mappings. The following list is a set of cases in which we compare the methods of lexical similarity with the methods of semantic matching to analyze and integrate concepts and relations. In some of these cases the lexical techniques do not give satisfactory results.

The possible verifiable combinations are the following:

1. the concepts and the relations linking them have the same names and the same semantics, it is undoubtedly an ideal case
2. the concepts and the relations linking them have the same names but different semantics, in this case the lexical techniques could produce mistakes
3. the concepts and the relations linking them have different names and different semantics, this case will never be computed by lexical similarity techniques, but a semantic analysis is necessary

We can not use methods of lexical similarity in ontologies of different topics where there is not overlapping of concepts. In that case we will not obtain results. Therefore, we use methods for comparing and managing semantic relations. The methodology to identify the mappings is based on comparing two set of relations extracted from two ontologies of the same topic (e.g., medical ontologies, device ontologies, etc.). Analyzing the sets and the meanings of relations we can draw a Table 1 in which each kind of associative relation extracted by the first ontology is associated with its synonym extracted by the second one. For example, in the ontology A a relation is defined with the string *isMemberOf,* in the ontology B we find the relation *isElementOf,* since their meanings implicate a membership the two relations can be mapped becoming two semantic bridges. We will see in the next example how the semantic bridges are used to integrate knowledge.

Table 1 - Example of correspondences between relations

Relation from Ontology A	Relation from Ontology B	Definition	Example
is-a	subset	subsumption	PDA is-a device
part-of	isBranchOf	meronymy	keyboard is part of cellphone
isMemberOf	isElementOf	membership	professor is member of the faculty
isEquivalentOf	asSame	equivalence	professor is synonym of teacher
hasAttribute	hasQuality	attribution	printer hasQuality pageSize
hasInfluenceOn	determines	dependence	bandwidth influences response time
isAssociatedTo	isRelatedTo	association	calling is related to telephone

[9] http://wordnet.princeton.edu/

Therefore, the semantic bridging phase is responsible for establishing correspondence between the main associative relations among concepts.

In the framework of topic ontologies for MILK we built a set of semantic associative relations describing the more general links among concepts of the domain. These associative relations link together pairs of equivalent concepts between ontologies of the same topic, and concepts that can be correlated according to their semantics between ontologies of different topics. First of all, we search the mappings by identifying some associations frequently recurring between relations and concepts in an ontology, and these associations carry out a task similar with those which exist in another ontology. Then, we identify two *anchors*, that is, two concepts used for matching the associative relationships (as the term is used in the mapping techniques [23]). These relations are compared computing the number of times each of them links concepts to the corresponding anchor, this task aims to highlight the relations linking such anchors in the target ontology. The relations which recur more often between the two anchors are identified as the most relevant. Now, if the two pairs of concepts are equivalent the relations have to be coupled by type. The associative relations can be represented as links between the former concept (subject) and the second (object).

In next example we integrate a new part of an ontology in the set of ontologies of previous example of the contract using associative relations as bridges (Fig.2).

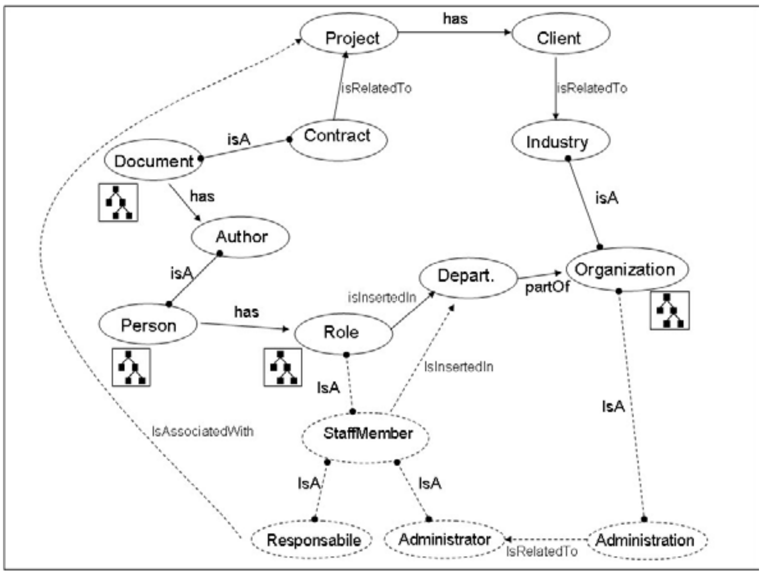

Fig.2 **The integration of Role topic ontology**

To include information about the roles of people not defined before, we evaluate the associative relations of a new part of ontology. A person inserts the role *StaffMember* in his description and a *Department* where is included in, and also he declares that he is responsible for a project. Now these information are stored as subclasses of *Role,* and are characterized by relations *isInsertedIn* and *isAssociatedWith.* In the ontology about the roles we have the concept *StaffMember,* (*StaffMember isA Role*) described as follows: *StaffMember* → *isInsertedIn* → *Department.* Then we find the concept *Responsible*, which is a sub type of *StaffMember* (*Responsible isA StaffMember*). This concept is linked with the relation *isAssociatedWith* to the concept *Project*: *Responsible* → *isAssociatedWith* → *Project*; from the previous table we discover that the relation *isAssociatedWith* corresponds to *isRelatedTo.* We assume that this second relation links also the concepts *Administrator* to concept *Administration*. *Administrator* is also a sub type of *StaffMember* (*Administrator isA StaffMember*). Therefore, the concepts *Responsible* and *Administrator* inherit the properties of concept *StaffMember*, hence they are linked to *Department* and *Administration* is a sub type of *Organization*. In the picture the addiction of nodes and arks with dashed lines to the previous graph symbolizes the integration of new information.

The semantic bridging phase allows for us with semantic patterns to interpret the context in a certain situation, but this phase requires a level of reasoning whose discussion has not space in this paper.

The fifth phase focuses to evaluate and keep the semantic bridges (the mappings between the relations) in synchrony with the changes in the ontologies, and to establish a consensus on semantic bridges between two communities participating in the same information system. But, now we must illustrate some examples of semantic navigation of our framework to better introduce the second case of study.

4 Semantic Navigation

When people are involved in activities requiring working with information they need to access a great mass of knowledge. Moreover, when a user is creating a document, he needs to connect his ideas to knowledge which is available and shareable. The creation of new knowledge always occurs in a certain context, within the individual and the common knowledge. This knowledge is a mix of existing information and new individual ideas, and it can be expressed by personal or common ontologies (topic ontologies).

We can consider a set of topic ontologies as the semantic context of a certain document or a piece of knowledge. What is the user doing, what was the user doing in the last hour, day, year; what are relevant topics for user's company; and much more can be used to capture this context. We also know that the context is not fixed, but it may change according to user activities: for example, a user does most of his work on a project writing some texts, but during the day he may switch to another context, for example to prepare a lesson for a course. These context switches should be detected and used, because they require change of topics. We refer to the possibility of changing semantic context and the related change of topic as "navigation".

Another point to consider is that, due to users' particular needs or specific models of knowledge, different views can be proposed about the same set of documents. A user can create personal schema to classify his/her knowledge according to hierarchies of categories that form the different topic ontologies. Semantic navigation is a way to build up and navigate views according to the logical organization given by the topic ontologies.

The Semantic Web techniques can help in manipulating these structures that can be organized according to standards such as OWL. We propose to navigate these structures using semantic relations as explicit links.

Semantic navigation via links is the only way for users to interact with the system, and it determines their ability to retrieve the desired information. Similar approaches and issues relating to the design and implementation of navigation structures can be found in [26][27][28].

In the MILK project we have developed a new approach to interact with users [17]. With the traditional searching features, the MILK system provides the user with a discovery feature that fetches and shows information that is related to the current user activity and hence to the context. Discovery is addressed by the *view with context*, a metaphor realized in a profiling mechanism that binds elements of different nature together (Fig.3). On the screen, the element a user has retrieved (e.g., a document) is displayed surrounded by other elements that are similar to it (e.g., related documents, expert people and projects on the same subject). In such a way, users become aware of what is available and can discover novel information.

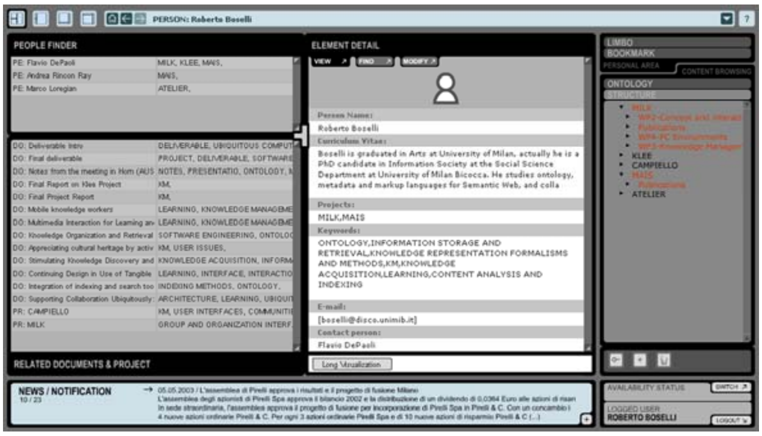

Fig.3 The MILK view with context interface

With the description of elements displayed on the screen, also the topic ontologies are displayed as supporting tools to classify, retrieve and discover novel knowledge. Also the personal schemas are visualized on the interface and OMEC provides possibilities to create new schema. The user can access the stored data via OMEC in such a variety of ways: he can follow a path across his schema created from scratch; he can follow the links of concepts in the available ontologies; he can select a type of relation and follow the paths they draw across the ontologies; he can make a query and following the results of system. We illustrate an example of navigation starting from a query and browsing the results returned by the system.

We recover the example of contract to better understand how OMEC supports user navigation. We must consider the path between the elements of Fig.1 as a formal representation of a possible *view with context* starting from a concept of the path. A user can start with a simple query typing a single concept (e.g., *Project)*, then OMEC returns the topic ontology where the concept is classified. The view of the topic ontology is divided into three panels: the Class panel, the Relation panel and the Instance panel (like in Racer). The Class panel represent the tree structure of ontology, and the term searched is selected in its exact position in the hierarchy. Once the term is selected two distinct lists in the other two panels are visualized: all the corresponding relations (the properties of the term *Project*) and instances (all the names of the projects included). Clicking on a relation (e.g., *isRelatedTo)* in another panel are displayed all the concepts related by it to term *Project* and all topic ontologies involved by that relation. Now the user can choose to select one of the concepts (e.g., *Investment*) or browse into one of ontologies. If he clicked on term *Investment* OMEC opens the three listed panels of the corresponding topic ontology. At this time the user searches a specific instance of *Investment* into the Instances panel where he can see the metadata and finally open the files classified under that concept.

An alternative way to navigate is by starting from an instance. So, in a bottom-up direction we find a list of properties related to the instance names, and the values, so starting from a specific instance it is possible to find all the properties, concepts and objects linked. Besides accessing existing artefacts, this semantic navigation can also support a design phase, by clustering attributes and properties associated with different bodies of knowledge. This second kind of navigation is the specific focus of the experiment described in the next section, where by selecting certain qualities is possible to discover which type of service has them.

5 MAIS Project

In this section we discuss the framework applied to MAIS project that made use of integrated topic ontologies to support design and selection of Web services. The context of the project is mainly related to software engineering and we are interested to focus the social reasons and consequences of the use of ontologies.

The goal of MAIS is the development of a platform for the creation of adaptive and flexible information systems. To this end, MAIS defines a reflective architecture supporting the creation of a system that is able to observe and control its own structure and runtime behaviour. In the MAIS architecture, reflective knowledge is expressed in terms of QoS. QoS means that, given a certain service (e.g., localization service, displaying service, etc.) the middleware lets the application access and possibly control its characteristics (e.g., the bandwidth, the size and resolution of the screen, etc.).

Our experiment was to supply rich descriptions of Web services to address the perspectives of developers, providers and final users. At design time, ontologies provide a view on qualitative and quantitative aspects, in terms of Quality of Services (QoS), and their relations with technological aspects (devices, channels, etc.), social aspects (user profiles, communities) and environmental aspects. At discovery time, associative semantic relations allow for the discovery of new contents and new views on domain. The use of different topic ontologies in MAIS becomes part of Web services development, exploiting ontology functions of understanding, classifying and reasoning on knowledge related to different aspects involved.

In this context the user requirements are relevant aspects to define the needed services, and the requirements are typically collected from interactions with domain experts that supply knowledge on user roles and domain processes. The approach is to consider quality aspects derived from business requirements, and incorporate and refine them along the design process. The designers can use and navigate the ontologies and/or augment them to understand how to fulfil their requirements. In other terms, ontologies support understanding of mutual connections and are a means to capture novel connections discovered by designers.

Four ontologies have been developed within the project:

- Quality of Services Ontology (OntoQoS)
- Architecture Ontology (OntoArch)
- User Profile Ontology (OntoUser)
- Service Ontology (OntoServ)

OntoQoS is the most peculiar ontology in the MAIS project since it is a unique effort in classifying the qualities that can be associated with all the issues related to services. OntoArch and OntoUser describe the concepts that define the context of the service. The former deals with the definition of the conceptual channels defined by devices and networks, while the second defines the roles of users. OntoServ has the purpose of classifying the different services according to domain characteristics. All the four topic ontologies are integrated and managed by OMEC.

The use of OMEC with the methodology of Web services design is still in development and many technological aspects have still to be evaluated, but in the context of this paper we consider that factors related to navigation crossing the user profiles and the ontologies.

We take into account some typical roles of people related to Web services domain: provider, client, developer and business expert. Each of them has a personal view of the topics and the relations existing between the technological, business and social concepts underlying the Web services design. We can also say that each of them has proper topic ontology of the domain, also within a same organization.

The structure and metadata of the profiles of developers, providers and business experts are quite similar. But the knowledge visualized according with the profiles can not be the same, as well as the use of the topic ontologies. The navigation of knowledge is influenced by the specific goals of every user. For example, a user with role *Developer* is interested during a design phase to topics concerning *Programming languages* or *Information systems,* so he may be a member in the same time of a community of *Programmers* and one of *Web Designers*. If he is using topic ontologies to design a Web service, he navigates OntoServ ontology to find similar services to what he must develop. But in the framework the OntoServ is integrated with OntoUser, hence the developer is supported to address some social aspects, like disability restrictions, related to specific end-users. While a provider is interested to business details, so for example dealing with the same ontology he obtains information about the costs of the service implementation. The cost of the service is a quality strictly related to the profile of the end-users, so the provider must take in account which is the target user linked to that cost.

What is strategically innovative in our approach is to support the experts, not only the software designers, in the identification of non-functional requirements of the services. By means of the service ontology OntoServ the designers can classify the new service and, through the relations in the ontologies, became aware of the typical qualities and the most relevant characteristics associated with the users and the distribution channels. The use of ontologies is therefore strategic to support the expert in the definition of the desired qualities. The designer, by browsing from top-level QoS (e.g. availability, security) of OntoQoS, finds the most interesting QoS that services must offer to end users. Once a QoS dimension is identified, it is possible to extract from OntoQoS other QoS dimensions semantically connected with the selected one. In much similar way, experts can exploit user and device ontologies (OntoUser and OntoArch) to identify the context for the new service.

The same person can have two different profiles, that is, in the framework the possibility to define a free profile that reflects other aspects of his personality is given to users. A designer could prefer to use his profile as client to have different contexts and different behaviours from the system. In fact, a designer who prefers to access the information as *Client* exploits a set of different topic ontologies. For example, if he loves art exhibitions, his profile metadata will reflect his cultural interests. In this case the context concerns a free time activity and the systems switches to services already defined in the OntoServ. So, in our framework the OntoServ ontology will show the services of ticket reservation of an exhibition related to information on the user preferred painters and he can choose which exhibition to visit.

6 Related Works

The present work addresses issues in the field of Semantic Web and Knowledge Management, with a particular attention to the new experiences of design of Semantic Browser and Semantic Desktop. In the last years, a few attempts there were to produce specification and implementation of the so-called semantic web browsers (MagPie [30], mSpace [31], Haystack [4], Liquid Information[10]).

An example of a user interface that gives normal humans the ability to interact with RDF is Haystack. Haystack brings the Semantic Web to end users by leveraging key Semantic Web technologies that allow users to easily manage their documents, email messages, appointments, tasks, etc. The Haystack user interface is capable of visualizing a variety of different types of information. But the prototype system developed is quite complicated and had performance problems that in the upcoming version of the project should be solved. Another recent tool is SWOOP, an ontology browser and editor developed at University of Maryland [36]. It is designed specifically for using OWL ontologies and directly supporting the use of Web applications to interact with documents. SWOOP supports the interactions with

[10] http://www.liquidinformation.org

remote ontologies using the URIs and the UI metaphor of hypertextual navigation but it does not offer great advantages in terms of semantic navigation.

We realize that our work goes to the direction of the field of Semantic Desktop. This area is not new (the term exists since 2003 [32]) and its main goal is to transfer the Semantic Web to desktop computers, but only recently the computer science community has developed the means to make this vision a reality. In the Workshop on Semantic Desktop at last ISWC Conference many tools and applications have been shown [33]. It is undoubtedly a field rich of good perspectives to consider for a future development of MILK system.

The MoSeNa [29] conceptual model is a semantic navigation model whose approach is close to ours. The goal of that work is to align web-based information systems to the needs of users and to improve the development and information retrieval. Mainly their second aim is relevant, to provide users with meaningful navigation structures. They argue that navigation structures should resemble existing structures or hierarchies existing within an organization. These hierarchies and structures constitute a multidimensional information space, which can be used to classify all content within the system. But our approach is different in terms of exploiting and integrating multiple and distinct ontologies in a modular framework with features to cover multiple tasks.

7 Conclusions

In this paper, we presented an approach to semantic navigation based on multiple topic ontologies. Our aim is to support users with semantic descriptions during some their tasks, as modeling, presentation and selection of knowledge classified in documents and according to their needs. The integration and distinction of different topic ontologies allow for effective richness and variety of views on a same domain, felt as a crucial aspect within an organization. With the elicitation of the semantic relations among ontology concepts it is possible to create new semantic patterns within a specific context, as seen in MILK and MAIS projects. The framework of topic ontologies and the developed tool OMEC provide users new interactions and ways of using knowledge, exploiting Semantic Web techniques to access, browse and discover new contents in a human-readable fashion.

We have outlined how topic ontologies model and relate the metadata profiles of elements classified, and how these correlations allow for retrieving artifacts, but not only. We have also introduced how topic ontologies support a methodology of Web service design in the MAIS project, mainly focusing on the relevance of social aspects into a development of an information system. Social aspects are becoming always more crucial to make the Semantic Web vision a reality.

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