Towards Semantic Web Portals

Michael Stollberg, Holger Lausen, Rubén Lara, Ying Ding, Sung-Kook Han, Dieter Fensel
DERI – Digital Enterprise Research Institute
Leopold-Franzens Universität Innsbruck
{michael.stollberg, holger.lausen, ruben.lara, ying.ding, sung-kook.han, dieter.fensel}@uibk.ac.at

Abstract

A web portal is a platform for information presentation and information exchange over the Internet in a community of interest. Conventional web technologies used in web portals present serious limitations regarding facilities for search, access, extraction, interpretation, and processing of information. Thus, support for information sharing and communication in web portals is confined due to limitations in the underlying technologies. Semantic Web technologies have the potential to overcome these limitations, hence utilizing them as grounding technologies will facilitate much more sophisticated web portals. Following this context, the aim of this paper is to expose the idea of Semantic Web enabled web portals. We therefore present a wide-coverage framework that indicates possible functional improvements as well as technical requirements for such web portals in detail. We then relay results of a survey wherein we have examined the utilization of Semantic Web technologies in existing web portals, concluding in future requirements for the development of Semantic Web enabled web portals.

1. Introduction

The impressive growth of the Internet in the last decade has made a huge amount of information available throughout the world. Various communities have made use of the web to strengthen communication and information exchange, not only within themselves but also with external communities or individual users. For this purpose, miscellaneous web portals have appeared that collect and present relevant information for the community, and wherein users can publish events or information to the community. For supporting this, a web portal should provide easy-to-use facilities for locating and retrieving information in the portal as well as services for communication and information exchange between portal users and between different communities of interest [8]. To realize these functional requirement, web portals have to become complex web applications.

At this point of time, conventional web technologies are used for building web portals, offering a straightforward means for creating and accessing new content on the Internet. Nevertheless, these technologies have serious limitations in making information accessible for users in an efficient manner. A general shortcoming of existing web technologies is that their support for essential information processing facilities, like search, access, extraction and interpretation, is very imprecise and weak. As these limitations are inherited in web portals, the quality of information exchange and communication support is naturally restricted. Semantic Web technologies [7] aim at overcoming these deficiencies. Ontologies shall provide machine-processable semantics of data and thus enable semantically correct communication and information exchange between different agents (software and people). In addition, Semantic Web Services aim at facilitating distributed computation over the Internet by combining the advantages of the Internet as a world-wide information exchange infrastructure with computational facilities [6].

Hence, Semantic Web technologies can considerably defeat the shortcomings of current web portals in multiple ways. At first, the elementary information processing facilities of web portals can be improved by applying Semantic Web technologies as the technical basis. Secondly, a new feature can be added to web portals as Semantic Web technologies allow interoperability of web portals and other Semantic Web driven applications. In this sense, Semantic Web enabled web portals (SW portals for short) represent the next generation of web portals. As a general definition we restrict the scope of SW portals to the following:

- It is a web portal, i.e. it collects information for a group of users that have common interests [12]
- It provides facilities for communication and information exchange within a community of interest as well as between different communities
- It employs Semantic Web technologies for advanced communication and information exchange facilities.

This paper investigates in detail how Semantic Web technologies can improve web portal facilities and derives requirements for the realization of SW portals. We therefore present a framework which covers the relevant aspects of SW portals and depicts required technologies. Then we portray the state of the art in SW portals based on an evaluation of existing efforts. Out of this we obtain future guidelines for the development of SW portals.

The paper is organized as follows. Section 2 presents our framework for SW portals along with requirements for technological realization; section 3 portrays the state of the art of SW portals by summarizing the results of our survey on existing efforts; section 4 exposes related work; section

5 concludes the paper and indicates future directions for SW portal development.

2. SW-Portal Framework

This section presents the framework developed for SW portals. The aim of this framework is to allow an overall functional description of SW portals and therein point out reasonable usage of Semantic Web technologies.

In general, a SW portal is a complex application that consists of several components. In order to identify all its relevant facets we distinguish three different layers, each of them describing a SW portal from a different perspective. The first is the **Information Access** layer, which describes a portal from the user perspective. The usability of the user interface and the quality of information available in the portal are sited here. The second is the **Information Processing** layer for describing the information processing facilities of a portal by a 5-phase processing workflow for information items, wherein the technical realization is of major interest for each phase. The third is the **Grounding Technologies** layer which embraces the technologies used in the SW portal for realizing the upper layers. Figure 1 gives an overview of the layers and their relationships.

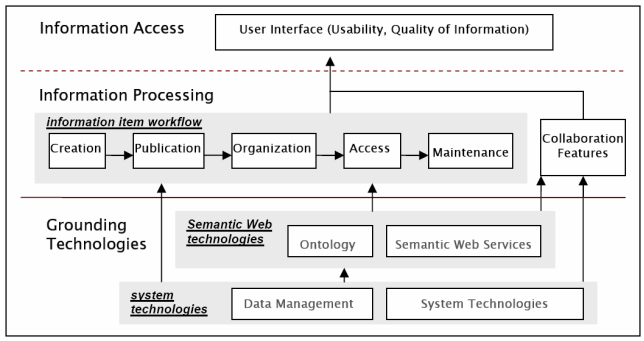

Figure 1: Description Layers for Semantic Web Portals

This layered scheme comprises the relevant aspects for an overall description of SW portals. It allows a precise examination of which technologies are utilized in what way, thereby pointing out potential functional improvements by using Semantic Web technologies in web portals accurately. It is important to note that our scheme does not imply a recommended architecture for SW portals. We aim, however, at illustrating SW portals exhaustively from a functional point of view, i.e. depicting their features in terms of a functional analysis. The construction of this scheme has been inspired by previous work in [8] and [14].

In the following, we explain the components of our framework in detail, indicating the relevant aspects for a fully-fledged description of a SW portal. The arrangement of the components' presentation follows a bottom-up approach. First we reveal the relevant aspects of the Grounding Technologies layer, as these underlie the features of the upper layers. Then we consider the Information Processing layer, and finally the Information Access layer is depicted.

2.1. Grounding Technologies

As shown in Figure 1, the Grounding Technologies layer contains the technical building blocks of a SW portal. We distinguish System Technologies and Semantic Web technologies: the former covers conventional web portal technologies used and the latter is concerned with the usage of Semantic Web and Semantic Web Services technologies.

2.1.1. System Technologies. The first group of components covers conventional technologies used in SW portals as web applications. This gives an initial overview of the portal.

System Architecture

Design. The general system architecture which usually is a common three-tier architecture (data storage, application logic and presentation tier).

Server Side Technology. The web server technology used as well as other server side technologies is denoted.

User Interface Technology. The used UI-technology (static / dynamic HTML, JSP / ASP, applets, etc.).

Data Management

Data Storage. The data storage devices are denoted (Database, RDF-Repository, etc.). Also, the kind of information stored is indicated (information items, user-data, ontology-data, etc.).

Sorting and Indexing. Sorting and indexing techniques improve the performance of data storing and retrieving. This can be a full text index or other techniques to organize meta-data.

Data Transfer. Denotes the data formats and transfer protocols used. In particular, the transfer between different components as well as between the layers of the framework is of interest.

System Maintenance

System Administration. This refers to facilities for maintaining a SW portal, including information items, user data and ontologies as well as tool support for runtime system administration. This aspect will be covered later in more detail.

Security Technology. Here technologies for ensuring safety of information access in the system are considered. These can be, for instance, the usage of SSL-connections or password-protection for private areas in a SW portal.

2.1.2. Semantic Web Technologies. The Semantic Web technologies to be utilized in SW portals are ontologies and Semantic Web Services. We specify their potential employment in order to indicate possible improvements of web portal facilities. Besides, the aspects announced below imply technical requirements for SW portals.

Ontologies

The central component of a SW portal is ontologies [13]. They define the terminology of the domain of interest and provide machine-readable semantics, thus enabling enhanced information processing as well as automated information exchange. These benefits can be utilized in SW portals in several ways: ontologies can provide the grounding data model of the portal, thus describing the structure and content in a coherent manner. Second, the information items in a SW portal can be semantically annotated and ontology-techniques can be used for much more efficient information management (see section 2.2). Third, ontologies enable automated information exchange over the web which allows interoperation of SW portals and other Semantic Web applications. Ontologies used in a SW portal are described by the following aspects.

Ontology Type. Different types of ontologies are distinguished according to the purpose of their usage, mostly domain ontologies and application ontologies are used in SW portals [11]. It is important to state the concrete purpose of the ontology usage in a SW portal.

Ontology Structure. An overview of the ontologies' structure and size provides a basic understanding of the ontologies used. The main concepts are described and the occurrences of ontological notions – concepts, properties, relationships, axioms – are quoted. Upper-level ontologies are denoted when used [10].

Additional Facets. Optionally further features of the ontology can be stated if they are important for describing the ontology. Possible aspects are internationalization, multilingualism, as well as the balance of expressivity and scalability of the ontology.

Inference and Reasoning

Inference mechanisms can be used to enhance the processability of ontology data. For example, a reasoner can check cardinality constraints and class membership or an inference engine could interpret symmetric or transitive relationships, depending on the ontology formalism. As for ontology-based applications in general, this is not a required feature for SW portals but it is likely in order to improve information processing quality.

Ontology Management

Ontology management techniques are essential for enabling Semantic Web applications in general, thus SW portals as well. This contains techniques that support evolvability and interoperability of ontologies to ensure long term usability of ontologies, and that guarantee semantically correct information interchange of Semantic Web enabled applications. General requirements for ontology management have been identified for ontology library systems in [5]. We slightly adapt them to the requirements for ontology management in SW portals.

Editing. An appropriate editing facility for ontologies has to be provided for editing ontology schema and instance data in a SW portal. This can either be an external editor or an editing facility integrated in the portal.

Ontology Search for Administration. To facilitate management of several or huge ontologies in a SW portal, appropriate support for finding a specific ontology or a part of an ontology is required. This can be realized by a search on textual descriptions of an ontology or by means for ontology browsing.

Maintenance / Versioning. An ontology schema, i.e. the concept level of an ontology, is a static representation of knowledge structures. As the domain of a SW portal may change over time, ontologies should be updatable to assure the topicality of a SW portal. Thus, ontology versioning techniques are required for tracing changes between different ontology versions and the resulting effects on ontology-dependent components [13]. Maintaining the maintaining information items in a SW portal, i.e. the instance level of a portal ontology, can reasonable be automated by inference-based techniques.

Standardization / Interoperability. A major improvement of SW portals is that ontologies enable interoperability and automated information exchange with other SW portals and Semantic Web applications. To attain this technically, a SW portal should support standard Semantic Web ontology languages (such as RDF or OWL), provide functionalities for export and import of these, and employ means for integrating ontologies [20]. For an advantageous SW portal, it is not only important to provide the required techniques but also to employ them in cooperation with other portals or applications.

Semantic Web Services

Web Services add a new level of functionality on top of the current web, transforming the web from a source of distributed information to a distributed source of functionality. Current research initiatives are concerned with semantically enriching web services in order to allow automatic discovery, composition, and invocation, emphasizing the concept of Semantic Web Services [3], [6]. The use of Web Services and Semantic Web Service technologies in a SW portal reflects to what extent a SW portal can be accessed programmatically over the Web. In this regard, the following aspects are of interest.

Functionality. The functionalities of a SW portal – e.g. content search, content publication, etc. – can be made accessible as web services. This allows using a SW portal not only through its user interface, but also programmatically. The degree of web service usage is described as a relation between the portal functionalities accessible through its user interface and those accessible through web services.

Provided Semantic Web Services. Enriching web services with semantic information allows automatic location, composition, invocation, and interoperation of services. In addition to portal functionalities exposed through web services it must also be considered to what extent these services include automation support.

2.2. Information Processing

This layer is concerned with the information processing facilities of SW portals implemented on top of the technologies identified in the Grounding Technologies layer. We consider the processing workflow for information items (a superordinate term for all kinds of information a SW portal contains) and thereby point out where and how Semantic Web technologies can be employed to enhance information processing capabilities of the SW portals.

As a skeleton for the Information Processing layer we utilize the "Document Life Cycle" as a starting point [9]. This has been defined for intranet document management systems and identifies 5 stages: creation, publication, organization, access and destruction / maintenance. We slightly modify this model for the information item life cycle in SW portals.

2.2.1. Creation. The first stage of the information item life cycle is the creation of a new item, i.e. adding information to the portal. In general, there are two possibilities for information item creation: either via the user interface or by importing existing items from other applications. New information items should be immediately assigned to the portal ontology as instances in order to guarantee the correct semantic annotation. Creation via the user interface can be supported by appropriate editing forms or similar means which should be based on the underlying ontology. For importing information items, techniques for integrating a new item with the existing ontology are required.

2.2.2. Publication. After a new information item is created it is published it in the SW portal. The point of interest here is how a new information item is made accessible to the community. This can be accomplished by establishing different user rights whereby users with appropriate permission control the quality of the information published. Improvements by using Semantic Web technologies in this phase are narrow.

2.2.3. Organization. This phase is concerned with storing and indexing information items in the portal's storage devices (the used devices are located in the System Technologies section). Here, the technique for storing ontologically annotated information items is major of interest. A SW portal should allow retrieval as well as import and export of ontology data in order to provide information exchange with other Semantic Web applications. It is not recommended to only use specialized ontology repositories, but information items have to be retrievable with the same ontological annotations that have been assigned during creation.

2.2.4. Access. This stage is concerned with the retrieval functionalities for the information items of a SW portal, i.e. how users can locate and access information available in the portal. Mainly the search facilities are of interest. Semantic Web enhanced search technologies should be applied as ontology enhanced search accomplishes significantly better search results than other information retrieval techniques, empirically proved in [1] and [19]. We distinguish the types of search facilities shown in Table 1, ordered by the degree of semantic enhancement.

Table 1: Search Types in SW portals

Search Type	Description
key word	simple search term matching
ontology browsing	browsing facility on schema and instances of an ontology
ontology search	full text search on property values of selected ontology concepts
inference-powered	ontology search enhanced with inference-based reasoning facilities

2.2.5. Maintenance. The last step of the life cycle is maintenance support for information items already stored in the system. For long term usability of a SW portal, it should be possible to modify, update or move information items if there are changes in the content or in the ontology schema, or delete them if they become irrelevant. Therefore appropriate mechanisms for ontology evolution are needed.

2.2.6. Collaboration Features. Besides the information item life cycle, we further consider collaboration features in the Information Processing layer. By this we mean additional features for communication and information sharing between users of an SW portal like, for instance, mailing features, discussion forums, or multiple-user editing of information items as a Semantic Web enabled feature. Collaboration features significantly provide added value for the user community of a SW portal.

2.3. Information Access

The third layer of the framework inspects a SW portal in terms of a usability from the user perspective and the quality of information provided in a portal. Although not all aspects in this layer are directly related to technical realization, they determine the acceptance and usage of a SW portal to a very high extent.

2.3.1. Usability. Usability addresses the relationship between a portal and its users by inspecting if a system is easy to understand, easy to use, easy to remember, error tolerant, and subjectively pleasing [4]. For describing the usability of SW portals, we refer to common heuristic inspection methods [16].

Maturity of Implementation. Refers to the completeness of the implementation in a SW portal. All functionalities should be properly operated without errors or broken links and sufficient error handling should be provided.
Personalization. Customization is a major merit of web portals. We distinguish personalization for single users and collaborative personalization, i.e. facilities to build virtual meeting rooms. These functionalities are usually realized as access-restricted information spaces wherein Semantic Web technologies can be used for advanced features.
Help and Documentation. Appropriate help facilities and documentation will assist users in using a portal.

2.3.2. Quality of Information. The second aspect of the Information Access layer is quality of the information provided in a SW portal. Users expect to find all information related to a field of interest in a valuable SW portal (coverage) and they also expect these information to be trustworthy for their purpose of use (reliability).
Coverage. The relevance and completeness of information offered in a SW portal can be described in terms of width and depth. The width of coverage inspects the scope of information provided in a portal, thus rating completeness. Depth describes the content of information items with regard to its relevance for the portal user community.
Reliability of Information Resources. Reliability of information provided by a SW means that a user can refer to them as correct, valid, up-to-date information. Therefore information items should be assigned with descriptive meta-data like owner, authors and their affiliation, creation and modification date.

3. SW Portals: State of the Art Analysis

In our framework we have drawn the ideal picture of SW portals. It is obvious that this picture does not match the state of the art in SW portals. This section reveals this by summarizing the results of an evaluation we have conducted on existing SW portals.

We utilize our framework as the evaluation scheme for analyzing existing SW portals as it allows describing SW portals completely. The aim of this evaluation is to detect the current state in realization of SW portals and to position existing initiatives within the idea of Semantic Web enabled web portals sketched out in this paper – i.e. utilizing Semantic Web technologies to facilitate enhanced information processing facilities and to enable interoperability with other Semantic Web applications.

At this point of time, there are a lot of web portals that make use of Semantic Web technologies in one way or the other. However, some of them can be seen as prototypical solutions with regard to the idea of SW portals presented here. In this category we investigated two academic efforts (Esperonto Portal, OntoWeb Portal) and two efforts of commercial companies (Empolis K42, Mondeca ITM) in detail. Thereby we intended to identify the applicability of SW portals in non-profit as well as in commercial application areas. Other SW Portals we inspected are: the SWWS portal (swws.semanticweb.org) the Mindswap portal (owl.mindswap.org), KA2 (ka2portal.aifb.uni-karlsruhe.de), and KAON portal (kaon.semanticweb.org). These have not been evaluated in detail because they only make use of Semantic Web technologies to a very small extent and are not considered as prototypical SW portals.

3.1. Evaluation of existing WS Portals

The following presents the results of evaluating the four SW portal initiatives that we have investigated in detail. As rendering the complete evaluation exceeds the scope of this paper, we only highlight those features of each portal that are most relevant for positioning the effort as a SW portal.

3.1.1. Esperonto Portal. The Esperonto Portal (www.esperonto.net) is developed by the Ontology Group at Facultad de Informática, Universidad Politécnica de Madrid (UPM). It serves as the intra- and extranet platform for the EU project Esperonto.

The portal relies on 5 highly interconnected ontologies, each of them covering one relevant aspect for R&D-projects. The technical foundation of the Esperonto portal is WebODE, an ontology engineering workbench developed at UPM that provides basic features for ontology-based applications like storage and retrieval, edition, and import-export of ontology data [2]. These components provide basic solutions for ontology-management, but not in a mature manner. Especially, the integrated WebODE editor is not powerful enough for high-quality ontology editing, the versioning mechanism is very basic, and there is no support for web services. WebODE provides import and export facilities, but there is no cooperation of the portal with other applications.

The Esperonto portal realizes the information item workflow following the way proposed in our framework, but also not in a very mature manner. Information items can only be created and maintained by administrators and the maintenance opportunities are very weak. The ontology-based search does not work properly. Concerning the usability of the portal, information presentation is not satisfactory because too much information is displayed on one page. The information coverage of the portal is restricted to the Esperonto project.

Summarizing, the Esperonto portal realizes the basic features of SW portals via the WebODE-platform, but it does not attain a level of maturity required for mature SW portals. The ontology management facilities are still not satisfying and especially the implementation of the information item life cycle as well as the design for information presentation hampers this portal from being a sophisticating SW portal from the users' perspective.

3.1.2. OntoWeb Portal. The OntoWeb Portal (www.ontoweb.org) is a community portal academic and industrial partners interested in the Semantic Web. It has been set up as part of the EU project OntoWeb.

The portal is built up on the ZOPE Application Server and the Content Management Framework (open source components from ZOPE Cooperation, see www.zope.org). These components provide the basic architecture of the OntoWeb portal and they cover all the data management, chosen to achieve high performance and scalability. The second building block is the OntoWeb Ontology, a light-weight ontology (maximum depth is 4 levels; the properties are mainly Dublin Core-elements with few extensions). It defines meta-data for all content types available in the portal and all information items in the portal are treated as ontology instances. Information items are stored in the object database supplied by ZOPE by mapping the ontology structure to the repository.

A significant drawback of the OntoWeb portal is that ontology management features are very weak. The OntoWeb ontology was designed as a static, non-evolving ontology, thus there is no versioning mechanism, nor support for editing the ontology schema. A RDF-export-facility has been added in the latest portal version which remaps the information items from the repository to the ontological annotation, but import of information items is not supported. The connection to the OntoWebEdu portal (qmir.dcs.qmul.ac.uk/ontoweb/index2.html), which uses the OntoWeb ontology as its grounding data model, is first step into cooperation of SW portals.

Regarding the Information Processing layer, the support for the information item life cycle is elaborated on a very large extent, which can be rated as a prototypical solution in terms of our framework. In association, the usability of the portal is very high and quality of information is accurate due to a quality assurance step in the publication phase.

In conclusion, the OntoWeb portal is sophisticated from the users' perspective. However, the design of the grounding technologies appears to be curious. ZOPE offers a framework for web portals but requires additional effort for realizing sophisticated techniques for handling ontology data. This may hinder the OntoWeb portal to become a suitable SW portal.

3.1.3. Empolis K42. K42, developed by Empolis GmbH, is a knowledge management product that offers a basic infrastructure for handling Topic Map data whereupon web portals can be built. [1]

The core of system is the K42 server which provides management facilities for storing, querying, and maintaining Topic Map data on the basis of a self-defined Topic Map model. Topic Maps are a standardized technique for meta-data representation (ISO/IEC-Standard 13250), in terms of expressiveness comparable to RDF [15]. Furthermore, the K42 system contains tools for visualized access of Topic Map data as well as support for creation, publication and maintenance of Topic Map data. This tool suite provides basic functionalities for handling semantically annotated information in a web application. SW portal facilities have to be developed on top of this. We do not discuss the Information Processing and Information Access layer here since they are not part of the K42 system.

With the K42-system, Empolis offers a basic technology for SW portal development, using Topic Maps for ontology representation. As its facilities for handling and managing ontology data are very basic, it cannot be regarded as a sufficient SW portal technology within our framework.

3.1.4. Mondeca ITM. The Intelligent Topic Manager ITM (www.mondeca.com/english/produits_services.htm), developed by Mondeca, is a tool designed for knowledge management and automated knowledge acquisition.

Similar to the other inspected portals, the core of ITM is a back-end application that supplies the basic ontology data management and an ontology that defines meta-data for information items. In addition, ITM offers an extensive tool suite that is customizable for individual SW portals. It comprises the ITM Editor for editing and importing ontologies (supported standards: Topic Maps and OWL), a web front-end template including a graphical visualization for ontology data, semantically driven querying, and a knowledge acquisition tool using Information Extraction techniques. This supports building SW portals with a high degree of usability as shown in a demonstration portal which provides a sufficient realization of the information item life cycle comparable to the OntoWeb portal.

Shortcomings of the ITM technology are that there is no versioning mechanism for ontologies, the integrated ITM Editor is not powerful enough for sufficient ontology editing, and export of ontologies is not supported. In conclusion, ITM provides a proper development suite for semantically enhanced web portals, but, like the other portals examined, it does not provide sufficient support for ontology management and web services.

3.2. Evaluation Results

Regarding the state of the art in SW portal development, we conclude that all the SW portal initiatives inspected implement SW portal functionalities and features to a basic level, but not to the extent outlined in our framework.

Concerning the Grounding Technologies layer, all portals use ontologies as the grounding data model in the sense of an application ontology and support ontology representation standards like RDF, OWL, or Topic Maps. However, none of the portals provides satisfying means for

[1] Emplois changed its portfolio during our evaluation: the K42 development has been integrated within the e:kms knowledge suite, see http://www.empolis.com/.

ontology management; neither does any portal provide its functionality as Semantic Web Services, thus long term evolvability of SW portals and interoperability with other Semantic Web applications is not supported yet. Besides, none of the initiatives investigates uses inference or reasoning techniques for enhanced ontology data handling.

The evaluation of the Information Processing layer shows that most SW portals implement the information item life cycle in the way proposed in our framework, or at least follow this direction. It should be noted as a very significant drawback that collaboration features, although considered to be very important in terms of the service offered for users, are not existent in any of the SW portals.

Regarding the usability of user-interfaces, the OntoWeb portal and the ITM-template can be seen as prototypical solutions for SW portals with special respect to enhanced information presentation features like visualized ontology browsing. Concerning quality of information, only the OntoWeb portal offers a high quality; the reason for this might be that it is the only portal surveyed that is actually used by a sizable community.

The absence of sufficient solutions for support of Semantic Web technologies is naturally determined by the fact that individual technologies for ontology management, Semantic Web Services, and inference engines are still under development. Hence, they are not mature to be employed in applications and by no means at all yet combinable into a convenient framework for SW portals. Until these basic technologies have been completely developed, SW portals – and Semantic Web applications in general – will not be able to exploit the full potential of the Semantic Web which arises in interoperability and interchangeability of information and functionality. In this regard it is important to record that the portals surveyed are designed as autonomous applications not considering collaborations with other portals or applications. This shows that even the idea of evolving and interoperating applications, i.e. the idea of the Semantic Web, is not realized to a high extent at this point in time.

4. Related Work

The advantages of the web and especially of web portals as entry points for communication and information exchange have outlined in the work on the usability of web portals for governmental services by Gant and Gant [8]. The design guidelines for information-abundant web-sites by Sheidermann [17] point out the difficulties in creating user-friendly information portals on the web.

Ding and Fensel [5] conducted an extensive survey on ontology library. The focus is ontology management, which has been determined as a key part of SW portals. Based on this work we have derived the requirements for ontology management in our framework.

Maedche et al. [14] proposed a generic approach for developing semantic portals, *viz.* SEAL (SEmantic portAL), that exploits semantics for providing and accessing information in a portal as well as constructing and maintaining the portal. Although the focus of that work is different from the one followed in this paper, we received valuable input for the design of our framework. We extended their proposal by including further aspects and requirements, respectively, that we believe are relevant in order to achieve a fully-fledged description framework for SW portals. More precisely, our work adds the following aspects: functional ontology management (editing, versioning, interoperability support), Semantic Web Services, ontology-powered search, the information item life cycle model for describing the information processing facilities, and the Information Access layer.

Our work combines and extends existing work into a concise and exhaustive framework for SW portals. Such an overall framework is needed in order to derive significant comparison results on complex applications, as the ones we have obtained from our evaluation of existing SW portals.

5. Conclusions and Future Work

In this paper we have sketched a vision of Semantic Web enabled web portals as a future breed of entry points for communication and information exchange over the Internet, serving as advanced information repositories for human or machine consumption. Semantic Web technologies can improve web portal facilities significantly in various aspects. The main benefits are that, first of all, ontology techniques allow the structuring of a web portal as well as processing and presenting large amounts of information in a more sophisticated way than conventional technologies. Secondly, Semantic Web technologies enable web portals to interoperate with other Semantic Web applications, thereby establishing new web portal facilities.

We presented a 3-layered framework that provides a whole-coverage and concise characterization of all aspects relevant for SW portals, and that precisely identifies how Semantic Web technologies can be used to improve web portal facilities. In the Grounding Technology layer, we depicted ontologies as the core technology for SW portals and we identified requirements for ontology management and inference-based reasoning. Also, support for Semantic Web Service technologies is requested in order to enable programmatic accessibility of SW portals. In the Information Processing layer we pointed out how Semantic Web techniques can be used profitably to overcome the deficiencies in information processing of current web portal technologies. The Information Access layer exploits usage of Semantic Web technologies for enhanced information presentation.

We investigated the current status of SW portal development by summarizing the results of a detailed survey on existing SW portals. The most important outcome is that the portals employ Semantic Web technologies only in a very basic way, but not to an extent

which is necessary to exploit the full potential of SW portals as Semantic Web driven applications. Especially ontology management and support for web services are not mature.

With respect to this, we have to conclude that SW portal development is in a very early stage. This is mainly due to the fact that the technologies required are still under development and have not reached the industrial strength to be used in real world applications. With respect to this, we complete our work by stressing out the critical factors for making SW portals become reality:

Semantically Enhanced Information Management

Ontologies should be used to make use of the benefits for advanced information processing.

Advanced Ontology Management

Adequate Ontology Management technologies are needed for SW-portals. Thus techniques for (multiple user) editing, ontology versioning, and import-export of ontology data standardization have to be further developed.

Interoperability

Reuse and interchange of information and cooperation between SW portals should be supported in a SW portal.

Semantic Web Services

SW portals should offer their functionalities as Semantic Web Services to allow reuse of functionality from other Semantic Web applications.

Enhanced Portal Facilities

Collaboration features and other user-orientated facilities should be supplied to make it a more profitable place for information sharing and communication.

The work presented in this paper has been partially funded by the EU projects h-TechSight (IST-2001-33174), SWWS (IST-2001-37134) and OntoWeb (IST-2000-29243) . We like to thank Ann Johnston and Cliodhna Hurst for proof reading and the members of Digital Enterprise Research Institute (DERI) Innsbruck for fruitful input.

6. References

[1] Aitken, S.; Reid, S.: *Evaluation of an Ontology-Based Information Retrieval Tool*. In: Proceedings of ECAI'00 Workshop on Applications of Ontologies and Problem-Solving Methods, 2000.

[2] Arpírez, J.C.; Corcho, O; Fernández-López, M.; Gómez-Pérez, A.: *WebODE: a scalable ontological engineering workbench.* In: Gil, Y.; Musen, M.; Shavlik, J. (eds): First International Conference on Knowledge Capture (KCAP'01). Victoria, Canada. ACM Press (1-58113-380-4), New York, pp 6-13

[3] The DAML services coalition: DAML-S: *Semantic Markup for Web Services (version 0.9)*, 2003.

[4] Donnelly, V.: *Designing Easy-to-use Websites*, Addison-Wesley, 2001

[5] Ding, Y.; Fensel, D.: *Ontology Library Systems. The key to successful Ontology Re-Use*. In: Proceedings of the First Semantic Web Working Symposium. California, USA: Stanford University 2001; S. 93-112.

[6] Fensel, D.; Bussler, C.: *The Web Service Modeling Framework WSMF*. Electronic Commerce Research and Applications, 1(2), 2002.

[7] Fensel, D.: *Ontologies. Silver Bullet for Knowledge Management and Electronic Commerce*. 2nd Edition, Berlin: Springer 2003.

[8] Gant, J. P.; Gant, D.B..: *Web Portal Functionality and State government E-service.* In: Proceedings of the 35th Hawaii International Conference on System Science 2002 (HICSS-35/02).

[9] Ginsburg, M.: An Agent Framework for Intranet Document Management. In: *J. of Autonomous Agents and Multi-Agent Systems*, Kluwer, Boston, MA, Vol. 1, No. 2, pp. 271-286, 1999.

[10] Gómez-Pérez, A.; Benjamins, v. R.: *Overview of Knowledge Sharing and Reuse Components. Ontologies and Problem Solving Methods.* In: Proceedings of the IJCAI-99 Workshop on Ontologies and Problem-Solving Methods (KRR5). Stockholm: 1999.

[11] Guarino, N. (ed.) 1998a.*Formal Ontology in Information Systems.* Proceedings of the First Conference (FOIS'98). Trento, Italy, 6-8 June 1998. IOS Press.

[12] Heflin, J.: Web *Ontology Language (OWL) Use Cases and Requirements.* W3C Candidate Recommendation, 2003.

[13] Klein, M. and Fensel, D.: *Ontology versioning on the Semantic Web*, In Proceedings of the 1st Semantic Web Working Symposium, Stanford, CA, USA, July 30th-August 1st, 2001.

[14] Maedche, A., Staab, S., Stojanovic, N., & Studer, R. (2001): *SEAL - A Framework for Developing SEmantic portALs*. In Proceedings of the 18th British National Conference on Databases, July, Oxford, UK, LNCS. Springer.

[15] Moore, G.: *RDF and Topic Maps: An Exercise in Covergence*. XML Europe 2001 Berlin, 2001.

[16] Nielson, J., & Mack, R. L. (Eds.): Usability inspection methods. New York: John Wiley & Sons, 1994.

[17] Shneiderman, B.: *Designing Information-Abundant Websites: Issues and Recommendations*. International Journal of Human-Computer Studies 47 (1), 1997.

[18] Steffen Staab et al.: *AI for the Web - Ontology-based Community Web Portals*, 17th National Conference on Artificial Intelligence and 12th Innovative Applications of Artificial Intelligence Conference (AAAI 2000/IAAI 2000), Menlo Park/CA, Cambridge/MA, AAAI Press/MIT Press.

[19] Sure, Y.: Iosif, V.: *First Results of a Semantic Web Technologies Evaluation*, DOA'02, October 2002.

[20] Wache, H. et al..: *Ontology-Based Information Integration – A Survey of Existing Approaches*. In: Proceedings of the Workshop Ontologies and Information Sharing, IJCAI 2001.