# Defining Categories and Functionalities of Semantic Web Applications

Lidia Rovan, Tomislav Jagušt, and Mirta Baranović

***Abstract***— We argue that constant technological changes in the Semantic Web field are diminishing relevance of the proposed methodologies for development of Semantic Web solutions. Overview of the current trends and standards in the field of the Semantic Web showed that most of the basic building elements needed for Semantic Web application development are now standardized. We suggest that providing unique development methodology for all Semantic Web applications is not satisfactory and that specialization of methodologies is needed. To establish foundation for such methodologies we conducted an analysis of Semantic Web solutions in order to define Semantic Web application categories and their common functionalities. In this paper we present our categorization scheme and provide generalizations of common Semantic Web application functionalities.

***Keywords***— categorization, development process, semantic web, functionalities

## I. Introduction

From its beginning, Semantic Web is a very live and changing scientific field. For this reason the results of work in the area of Semantic Web application development tend to become obsolete in a short period of time. Also, since its original appearance, the Semantic Web has seen many changes in its core architectural layers, and even today, many of core building elements are still not standardized. Furthermore, there was a change of focus, from the original idea to build semantic agents [5], which induced the research in the Semantic Web as platform (eg. semantic web services standards) to the latest development directions that are focused on the "Web of data" or "Linked data" principles [4]. We made an overview of the current trends and standards in the field of the Semantic Web. We also made an overview of the current trends in the Web application development process. It showed that most of the basic building elements needed for Semantic Web application development are standardized, and therefore can be used as a cornerstone for future Semantic Web applications. Trough analysis of existing Semantic Web applications that we conducted, a number of typical use-cases were identified, allowing us to propose categorization scheme of the Semantic Web applications. Categorization is an essential prerequisite for proposal of Semantic Web application development process as we believe that defining general architecture and development process for all Semantic Web applications would be at the too high a level of abstraction. Therefore, it is necessary to identify categories of Semantic Web applications and propose software architecture and development process for each of them. Also, to better understand the use of Semantic Web technologies within identified categories, we additionally conducted the analysis of common Semantic Web applications functionalities.

The paper is organized as follows. We start out, in Section 2 by defining Semantic Web application and elaborating the motive for the creation of the methodologies supporting the Semantic Web application development process. In Section 3 we provide an overview of the related work in this field. In Section 4 we present our conducted analysis and in sections 5 and 6 we discuss the obtained results. Finally, we conclude in Section 7 with a brief summary and a short outlook to future work.

## II. SEMANTIC WEB APPLICATION DEVELOPMENT PROCESS – NEED FOR THE METHODOLOGY

### *A. Semantic Web Application*

First, it is important to give a precise definition of the Semantic Web application since there are different understandings of that term. A number of existing papers [14], [31], [34] and available literature introduced various definitions of a Semantic Web application. The problem is that many of them are built upon a different, or not enough precise definition of a Web application. For that reason, we introduce definitions that we follow throughout our research:

Based on a Connalen definition [10], we define:

***Definition 2.1:*** Web application as a Web system in which a user action can change the state of a business according to the defined business rules.

***Definition 2.2:*** Semantic Web application is a Web application that depends on the Semantic Web standards for its successful execution.

To classify a Web application as a "semantic" it is sufficient for it to use semantic technologies in at least one of its functional components.

### *B. Development methodology*

Most mature Web design methodologies emphasize the importance of separating implementation of data model, behavior model and navigation (user interface). Clear separation of tasks which the solution has to meet improves the quality of design, which is crucial for achieving the re-usability of software modules as well as to ease the evolution and maintenance of application [18]. MVC shows – at an abstract level - how information from a database (a model) is transformed to a view that makes sense for a user [32]. Due to logical independence of three layers of the application, modification of one layer has minimal influence on other [39]. After the Model-View-Controller (MVC) form was recognized as a suitable solution for the Web development, many Web frameworks were based on it (e.g. Struts, Tapestry, Spring MVC). Although there were many changes in the modeling and application development principles trough years, a number of recent trends in the application development is still based on the MVC. At the moment, due to their immaturity, Rich Internet applications (Ajax programming frameworks) are mostly not based on MVC pattern. However, research shows the need for such solutions, so their number is expected to increase in the near future [25].

Software Engineering is the design and development of complex software using accepted engineering principles [23]. Semantic Web Engineering (similar to the Web engineering) is engineering applied to the Semantic Web applications. Although it is considered to be a cloned Web engineering, Semantic Web engineering contains new approaches, principles, methods, tools, techniques and guidelines that can meet the specific needs of a Semantic Web application. It is important to set up a strong methodology basis for the future development in the Semantic Web field in order to avoid a crisis similar to the "Web crisis" [13] that struck the Web development in its beginnings.

The development of Semantic Web applications significantly differs from the development of Web applications, and brings a number of additional challenges. Ordinary Web applications are primarily oriented toward human users, operate using unstructured data with informal logic and links between documents. On the other hand, Semantic Web applications are oriented toward human users and machines (software agents), operate with structured formal statements, and use a formal descriptive logic with the links between data.

We believe that proposing general architecture and development process for all Semantic Web applications would be at the too high a level of abstraction, and as such not useful. Therefore, as a result of this research we identify categories of Semantic Web applications, for which we will later in the research separately propose architecture and development methodology that would be in accordance with the current Web application development methodologies

## III. Related work

Previous research in the area of the Semantic Web applications development resulted in a number of development methodologies proposals [12], [17], [34]. We argue that those researches are no longer relevant, mostly because of the constant changes of the Semantic Web technologies, but also because of the changes in the Web applications development process itself.

Hera methodology [17] divides Semantic Web application in three layers: semantic, application and presentation layer. They do not propose general solution guidance, but only focus on the presentation layer generation. Since their work was created before appearance of the relatively new Semantic Web technologies, for example RDFa (Resource Description Framework – in – attributes) which significantly changed the way of presentation layer generation, Hera does not meet the current standards. Also, it supports only restricted navigational capability, which makes the methodology applicable only to the small set of applications, with restricted number of different use case scenarios.

Corcho et al.[12] proposed extension of the ODESeW framework [11] for Semantic Web portal development. The solution uses a specific MVC framework and non-standard technologies (RQL - RDF Query Language) and therefore cannot be used as a general guideline for the Semantic Web portal development.

Heitmann [16] conducted a research similar to ours - analysis of Semantic Web applications with the aim of discovering common design problems. But, his analysis included applications which do not satisfy the definition of the Web application. The relevance of that research is also questionable regarding the fact that analyzed Semantic Web solutions were developed before 2007 and only for the scientific purposes. In addition, the research focused on identifying only the most frequent architectural components, regardless of the category in which they usually appear and the way of their interconnection in such cases. However, our research suggested that each category has a specific set of functionalities and method of applying technologies for achieving such functionality.

## IV. Semantic Web Solution Analysis

As a part of annual European and World conference on the Semantic Web, there are contests for the best Semantic Web application. Also, W3C (World Wide Web Consortium) maintains a list of existing Semantic Web solutions. We analyzed Semantic Web applications based on the following criteria:

- Active projects from the W3C list
- Projects from the “Scripting for the Semantic Web” contest from 2005 to 2009
- Projects from the ”Semantic Web challenge” contest, from 2003 to 2008

The main goal of the analysis was to categorize the existing Semantic Web applications, but also to recognize the most frequent use cases, and typical challenges that are being solved by semantic technologies.

Also, it was necessary to identify the functionalities typical for the particular category. Their implementation in various applications differs because of the specific real life situations the applications are built for. We tried to recognize the most frequent design patterns, so by applying them we could suggest the generalization of functionalities.

Besides fulfilling the mentioned basic goals set on the analysis, the results also showed that the Semantic Web is moving towards the modern research directions, and tends to materialize the “Linked data” (“Web of data”) and “Web of tags” principles.

The sample set included 128 solutions (Fig. 1).

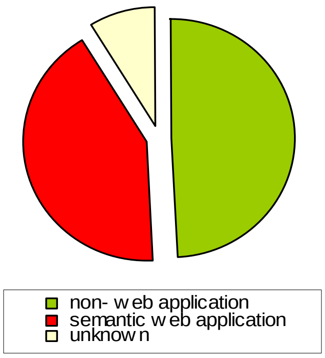


**Fig. 1 The sample set**

For 11 solutions, we could not find the documentation nor was the solution itself available, so the analysis is based on the remaining 117 solutions. About half of them (54) satisfy our definition of the Semantic Web application. The rest mainly consists of standalone applications, application frameworks etc.

During the analysis, we tried to match each solution with the corresponding Semantic Web research direction. The solution timeline confirms our assumption that the Semantic Web development moves toward new research areas such as “Linked data”. Fig 2. shows the distribution of solutions belonging to different research directions.

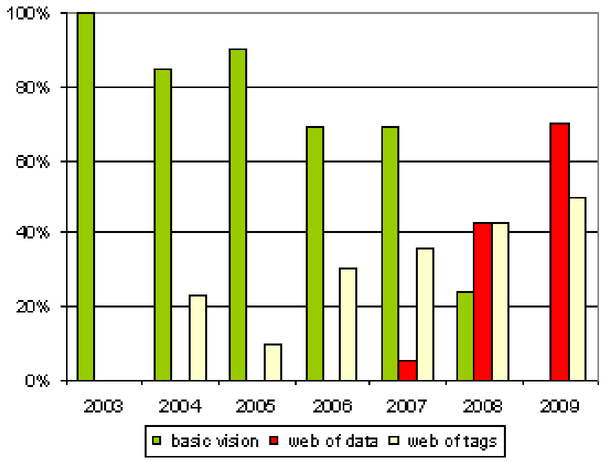


**Fig. 2 Number of solutions in each research direction over the years**

For solutions which are a part of multiannual projects, and were in different contests over the years, we considered only the most recent year, assuming that over the years the solution adopted itself to the trends. Also, it is possible that one solution belongs to more than one research direction (eg. ”Web of data“ and ”Web of tags”).

The solution is a part of a research trend if it has the following characteristics:

The basic vision – solutions that use ontologies with high-level logic as their data model, and are focused on gaining extra value from the model using reasoning. Typical applications examples of this research direction are the ones that support development of the main vision of the Semantic Web (eg. Swoogle – RDF and OWL search engine).

Web of data – program solutions built upon the rules from the “Linked data” concept.

Web of tags – the solution does not use ontology or “Linked data” model; it is aimed on tagging the data, usually using low-level logic. The tagging is typically performed by users, trough some custom interface.

## V. Semantic Web Application Categories

Before we started with the analysis of available material and online applications, the preliminary categories were defined. For the list of preliminary categories we did an overview of the similar researches in this area. There are a number of papers that deal with the categorization of classical Web applications [40]. The problem was that most of them were not specialized in Web applications (they also examined the Web sites). Furthermore, the applications considered in previous studies were made before 2002 and as such did not include the recent trends in Web development that enabled the creation of the new categories, for example social applications.

In his research, Heitmann [16] proposed the categorization of Semantic Web solutions according to three criteria: application domain, architecture type and application type. He divided the architecture into a centralized server with Web frontend, decentralized network of servers, standalone application and a peer-to-peer network. Evidently, Heitmann also takes into account the solutions that do not match the definition of a Web application. He determines the application type by functionalities that the application has, and claims that one application can belong to several types at the same time. The application type can be one of the following: a semantic portal, semantic annotation, semantic repository, semantic authoring, semantic desktop application and semantic scripting language. Unlike Heitmann’s assumptions, the hypothesis of our research is that the Semantic Web applications can be categorized according to their main purpose, regardless of the domain to which they belong. Also, it is assumed that each of these categories contains particular set of functionalities, and that the purpose and functionalities define the application architecture.

Finally, on the basis of previous research, we established following preliminary categories: Semantic Web portal, semantic knowledge management system and semantic recommender application. In line with the trends in the Web development, the category "social Semantic Web applications" was also added to the list.

In accordance with the literature and theoretical foundations, we made definitions for categories. The requirement that the category must meet the theoretical frame means that the assessors evaluated to what extent the applications met the requirements arising from the category definition given below. Every definition clearly outlines the purpose and functionality that is expected from the application.

The first step was to categorize the test sample, which resulted in revising the categories list. Then the categorization of all applications selected for analysis was conducted. In the analysis, we ignored the categorization claims by the authors themselves, since it seemed that they often differ from the theoretical frames.

Categorization was performed by two different assessors, which led to yet another adjustment of the categories. In the end, the following categories were formed (Fig. 3):

- Semantic Web portal
- Semantic knowledge management system
- Semantic Web recommender application
- Social Semantic Web applications
- Semantic Web expert system
- Applications that use semantic technology for content tagging
- Applications that use semantic technology to improve search results

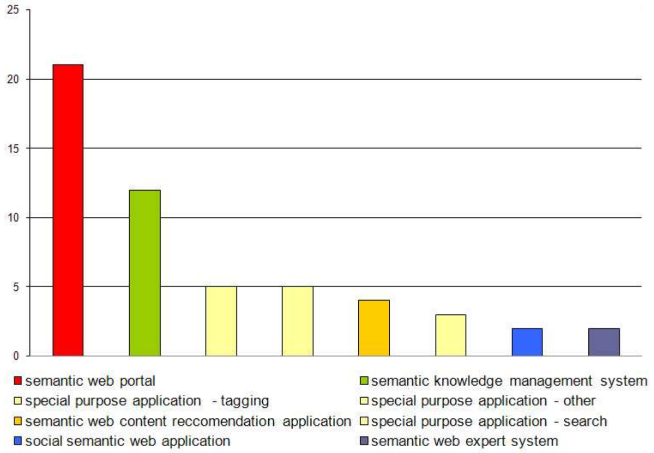


**Fig. 3 Frequency of the analyzed applications by defined categories**

### A. *Semantic Web portal*

Based on the research that Smith [36] conducted for the purpose of giving general definition of a Web portal:

***Definition 5.1 A***: The Web portal is an infrastructure that provides secure, customizable, personalized, integrated access to dynamic content from a variety of sources, in a variety of source formats, wherever it is needed.

In analogy to the definition of the Semantic Web application:

***Definition 5.1 B:*** The Semantic Web portal is a Web portal that depends on the Semantic Web standards for its successful execution.

Since the portal serves as a unique interface for gathering different heterogeneous data sources, the functionality it must have is the integration. Personalization and customization are less important, since their level of implementation in the portal fully depends on the domain the portal covers. Semantic Web portal usually uses semantics to improve integration, browsing, search and personalization.

### B. *Semantic knowledge management system*

Define In the literature, there are many papers on the topic of systems for knowledge [1], [23] and documents and content [7] management. Mostly according to [24], a knowledge management system is considered a superset of all afore-mentioned forms and is defined as:

***Definition 5.2 A:*** A knowledge management system is an application and a set of related processes that allows the identification, storage and retrieval of the intellectual capital to the particular organization (any type of organization) or a group of users that share a same interest.

The study conducted by Joo and Lee [19] identified the basic technical limitations of knowledge management systems that the Semantic Web technology could affect, namely the multiple data source integration, search implementation, user dissatisfaction with the system usability and the lack of consistency and completeness of knowledge. The study noted that Semantic Web technologies could provide a solution to the problems detected. In accordance with the research from Joo and Lee, the implementation of semantic technologies in knowledge management systems became one of the most frequent Semantic Web application categories. According to Joo and Lee research we give a definition for the semantic knowledge management system:

***Definition 5.2 B:*** Semantic knowledge management system is a knowledge management system that uses Semantic Web technologies to improve integration, search results, user satisfaction and accuracy of knowledge that the system handles.

Knowledge management systems are the systems used by the group of users with the aim of mutual knowledge exchange. Their main functionality, which makes them different from the other applications, is the ability to store and handle a variety of multimedia content. Semantic technologies in these systems are commonly used for improved document tagging, which enhances their retrieval.

### C. *Semantic Web recommender application*

According to Resncick and Varian, a typical recommender system is defined [35]:

***Definition 5.3 A:*** The recommender system is a system in which user provides recommendations as inputs, which the system then aggregates and directs to appropriate recipients.

From basic definitions we exclude the part which states that people are necessarily the ones who provide recommendations; the present technology allows a variety of ways to identify recommendations without explicit human input. The value of these applications is in the design of recommendation aggregation algorithm and in finding the proper relationship between the recommendations and those who search for them. Applying semantic technologies on these two key issues may lead to operational improvements. In the simplest cases of semantic usage in recommender systems, content and user descriptions are stored in semantic format (ontology) allowing identification of additional data by reasoning over the ontology. More complex semantic procedures use semantic descriptions also in the process of recommending content, by widening opportunities to analyze data and users. For example, a fuzzy decision-making can be applied, to create the non-determined relationships between objects and improve the search results [22]. The potential of semantic processes lies in the possibility to discover new knowledge about users, content, and their mutual relationship, which can be used in the process of content recommendation. In accordance with explanation we introduce the following definition:

***Definition 5.3 B:*** Semantic Web recommender application is a Web recommender system which uses semantic technologies for the purpose of conducting the analysis on which the user finds the recommended content.

Web portals that include personalization often implement a recommender system as well. In such circumstances, this category can be considered as a subset of the Web portals. In other words, that kind of Web portal is also a recommender system.

### *D. Social Semantic Web applications*

A social Web application is a term that has different meanings, usually broader than those defined in this research.

Often the term Web 2.0 is considered equivalent to social Web application [29]. Here we introduce stricter and narrower definition of social applications - oriented to the social networks. Therefore, the social Web application is focused on communication and collaboration among users. All other applications, where interaction between users is not the main goal of an application, are excluded from this category. An example is Wikipedia, which is often cited as a social application, but in fact it belongs to the knowledge management category, since it does not contain any form of user interaction.

***Definition 5.4 A:*** Social Semantic Web application is a Web application oriented to the social network that uses semantic technology to enhance cooperation/interaction among its users.

Social Web applications are a newer form of applications. These applications are aimed at any form of interaction between individual users, as well as within the user groups. Since the FOAF (Friend of a friend) gained huge popularity in the Semantic Web area, it is often used as a tool that allows distributed user profiles and implementation of social networks.

### *E. Semantic Web expert system*

According to Brooks [8], the expert system is defined as:

***Definition 5.5 A:*** An Expert System is a program containing a generalized inference engine and a rule base, designed to take input data and assumptions and explore the logical consequences through the inferences derivable from the rule base, yielding conclusions and advice, and offering to explain its results by retracting its reasoning for the user.

Thus, the expert system is a computer system that simulates the process of expert thinking while resolving a complex problem. It is used in problem solving or decision making tasks. Its purpose is to replace an expert in the particular field, her knowledge and the work she does. The defined rules represent the expert's knowledge whereas reasoning on the same rules represents an expert's work.

While building an expert system, Semantic technologies can be used to define data, a base of rules and reasoning over them, for example by using OWL. Also, since the data is semantically tagged, their interpretation is improved.

***Definition 5.5 B:*** The Semantic Web expert system is an expert system implemented as a Web application that uses semantic technology to define the rules, the inference over these rules and to improve interpretation of data.

This category is mainly used in very narrow domains, since it replaces the specific field experts and is not expected to be useful in a wide area of problems. Typically, the applications from this category are developed in the medical field.

### *F. Special purpose applications*

The remaining categories consist of Web applications that are designed to resolve specific business problems, thus it is not possible to generalize them into one of the categories above.

Such applications are further divided into categories depending on the way in which they implement the semantic technologies.

- Applications that use semantic technology for content tagging (the data is tagged using the top-down approach)
- Applications that use semantic technology to improve search results

***Definition 5.6 A***: Semantic special purpose application is a Web application that is oriented towards solving specific business problems of a domain using Semantic Web technologies.

## VI. FUNCTIONALITIES OF SEMANTIC WEB APPLICATIONS

During the categorization it was discovered that some of the features and functionalities appear in several different categories and cannot be taken individually as a categorization predictor. That is, the functionalities of applications by categories cannot be grouped in disjoint sets. For example, the search is a feature of a Web portal and a knowledge management system as well. For that reason, it is important to analyze the "big picture" of each category, i.e. the functionalities, their relations and benefits for the end user.

While performing analysis, it was important to identify form of usage of the Semantic technologies in the Semantic Web applications. Figure 4 shows the percentage of Semantic Web portal and Semantic knowledge management system applications that implement the common functionalities.

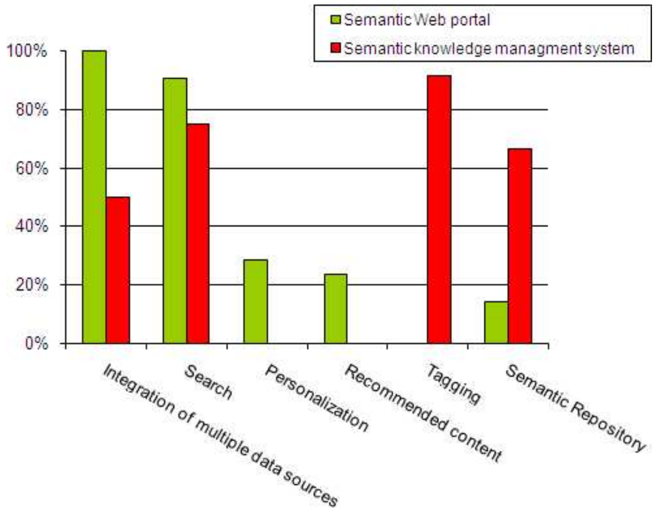


**Fig. 4 Functionalities by category**

Functionalities that are frequently implemented using Semantic Web technologies are:

- Integration of multiple data sources
- Search
- Personalization
- Content recommender
- Tagging
- Semantic Repository

When proposing architecture of the Semantic Web application categories, it is important to ensure that the architecture supports all the basic functionalities of the represented categories. To support as many implementations as possible, the architecture has to be created at a higher level of abstraction. Therefore, after the categories of Semantic Web applications are recognized, as the next step we have to make a generalization of the functionalities, in order to propose the architecture at a sufficient level of abstraction. In the text that follows explanations and generalizations for the functionalities of the Semantic Web applications are given.

### *A. Integration of multiple data sources*

The integration of multiple data sources was found in 38 applications from 54 that were analyzed.

The integration process is carried out in two steps:
1) Finding the data source that needs to be linked
2) Defining the relationship between data

Early Semantic Web applications (prior to year 2007) usually had a robot searching for semantic information across the Web. After the year 2007 none of the analyzed applications implements a robot tool for data retrieval. The use of Linked Data makes the need for this kind of implementation obsolete.

Since the automatic detection of potential data sources has not yet taken hold, although this idea exists from the very beginning of the Semantic Web, the sources still must be explicitly stated.

There are several ways of integration that need to be distinguished:
- Integration of the unstructured data sources
- Integration of the structured data sources
- Integration of the semantically annotated data sources

**Integration of the unstructured data sources**

When integrating unstructured data sources it is very complicated to make a generalization of that process. Unstructured data sources are usually the text documents. In order to obtain the meaning from the text documents, various methods from the “information retrieval” field have to be applied. The choice of algorithm and how it is being used depends on the language and content of the file. CS Aktive Space [36] is an example of the application based on the heterogeneous unstructured data sources. In the project, a special service for each type of data source was developed, and each source had to be treated separately. Flink [25] is also a good example of various format data sources integration, since it integrates text data as unstructured - electronic mail, structured - information on publications (Google Scholar), and semantics - User profiles (FOAF). In that project integration was implemented in a way that each source was treated separately as well.

Knowledge management systems mostly handle unstructured data, with the difference that here the content is usually created inside the system, instead of being fetched from other sources. In this case, a frequent method of integration is to input the tags and semantic data through various custom user interfaces. In this case, generalization is hard to achieve because the interfaces are application-specific.

**Integration of the structured and semantically annotated data sources**

Integration of the structured data sources is much easier because there are already numerous solutions for transforming databases or XML (Extensible Markup Language) documents in the semantically annotated data. After the transformation, the same methods that are used for integration of semantically annotated data can be applied.

To be able to semantically link various data sources, we need the ontologies. Today, a number of existing usable ontologies exist, but their re-usability depends on the domain of the application that is being implemented.

After finding the appropriate ontology or creating your own, depending on the needs of application, the conversion of data stored in relational databases, XML or other structured formats into the semantic records is performed. The data mapping is carried out with one of the existing mechanisms, e.g. D2RQ [7], Virtuoso[34], GRDDL (Gleaning Resource Descriptions from Dialects of Languages), etc... After all the sources are described with ontologies, they have to be interconnected. In most cases all the data sources are not immediately transferred in the same ontology, so it is necessary to connect the ontology schemes. Usually, this is done by introducing the "mapping ontology" that contains links between the concepts used in both ontologies. This step maps only the ontology schemes. The next step is performed to identify all the same instances. Here, we can use the inference based on the recognition of the unique features (identifying URIs) or similarity metrics when an explicit rule to search for the same instances cannot be introduced.

*B. Search*

A large number of applications, 39 of 54 analyzed, used the semantic technologies to improve search capabilities. Figure 5 shows the percentage of analyzed applications that implement semantic search.

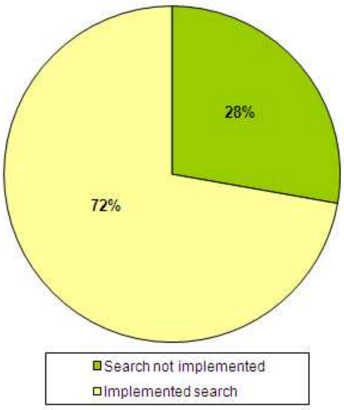


**Fig. 5 The percentage of applications implementing Semantic search**

The most common are "hybrid solutions" - a combination of traditional keyword based search with ontology-aided search (keywords are in some way described using ontology), the steps of the search procedure are still context-dependent. Data preparation, extraction and content tagging, similarity algorithms, etc ... depend on the type of the available content.

Although with limited possibilities, visual approaches to the search problem are also very popular - users select concepts and define the search parameters on the screen. Conventional approach to visual search is faceted search which was implemented in a total of 8 applications. Faceted search is a exploratory technique for structured data sets, based on the facet theory [30]. It is practical to use faceted search in cases where we do not expect the user to be familiar with the structure of a data that she searches trough. In this case, the information space is classified with facets, which are displayed to the user, and by selecting the value of facets, user filters the available information. Advantages of the faceted search are:

- Facet hierarchies give an overview of what information is contained in the repository
- Hierarchy can guide users in formulating queries so they will use the proper terms

A choice of the facet that will be offered through the interface depends on the application domain. Development of algorithms that search the facets or narrow the selection has the usual form [30]. In special cases such as SWEET [33], the search does not follow any global formats and is custom made for that specific application.

*C. Personalization and Recommended content*

Personalization, which may include recommended content, is a very complex topic. The functionality of the personalization, beside the recommended content, is a part of almost all portals and social web applications. Considering the three categories in which personalization makes sense, namely the Semantic Web portal, the content recommender system and social Semantic Web applications, a total of 12 applications from 27 of them have implemented personalization, which makes 44% of all applications in our survey. Figure 6 shows the distribution of applications that implement personalization.

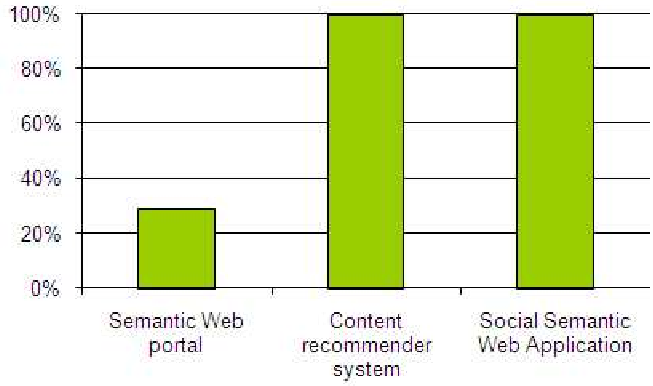


**Fig. 6 The distribution of personalization in different application categories**

The aim of the personalization is to provide users with what they want or need without requiring them to ask for them explicitly. [27]. Personalization process implies a lot more than the content recommendation which is just one aspect of personalization. The basic personalization is a process that occurs during the use of application by user, and consists of collecting information about user's preferences, which are later used to adjust the system behavior. For example, language and location settings, menu customizations, interaction reducing, etc. Overview of the personalization approaches is available in the [3]. In the analyzed applications various ways to achieve the personalization and recommended content (explained in the work of Anand) have been implemented, and there is no common personalization pattern. It was found that the basic problem of all implementations is inadequate access security level, and since it handles user profiles, i.e. personal data, this problem cannot be ignored. A detailed evaluation of the implemented solutions is quite difficult, since we have application prototypes, with an insufficient number of users and data. The MusiDB [38] explicitly states the problem of lack of users and data as the reason because of which a quality evaluation cannot be given.

*D. Tagging – the introduction of Semantics*

In the analyzed applications two basic ways of content tagging were identified:

- Automatic identification and tagging of unstructured content
- User created semantic tags

Similar to the functionality of integration and search, automatic content tagging is also a domain-dependent issue closely related to the information retrieval field so the solutions are difficult to generalize. The emphasis is on the information retrieval from a variety of formats, which requires special methods from the above mentioned field.

The latter tagging type, which belongs to the Web of tags research direction, is performed by users themselves.

The applications present different content tagging implementations. Comparison of existing methods is given in the paper by Kim and others [21]. Below, there are examples of implementation that were discovered during the application analysis. Projects Revyu.com [15] and GroupMe [1] implement free content tagging, allowing authors, owners or users of resources to create tags, which results in informal and anarchic tagging system, with ambiguity. Formally speaking, this approach means the content is labeled with tags described by the triples: tagging (user, source, tag). Drawback of this approach is the lack of real meaning, e.g. does the word "apple" mean "apple, the fruit" or maybe "the Big apple, New York". The solution offers a technology called MOAT - "Meaning Of A Tag". MOAT introduces the real semantics into tagging and completely eliminates the ambiguity of the tags using the quadruple: tagging (user, source, tag, meaning). We should mention the int.ere.st project [20] that uses SCOT (Social Semantic Cloud of Tags) ontology for semantic tagging. Their approach is fully oriented to folksonomies and tag sharing, which is suitable for use in social applications. Still, the ambiguity problem is present, so for a complete solution, integration with MOAT is necessary. SCOT ontology contains the concepts necessary for integration of the tags from different users, created in different applications, for a variety of sources, while MOAT gives the true meaning to such tags.

### *E. Semantic Repository*

Semantic repository has become a part of nearly every Semantic Web application. Although in the early beginning of the Semantic Web applications development there were some problems with a permanent data store implementation, now the technology is mature enough and implementation is not an issue. The current problem with permanent data repositories, especially important in the context of Semantic Web applications, is the access control. Only one project emphasizes the problem [9] and solves it by physical separation of data. while all other projects, although they have private and personal information that certainly needs to be protected, completely ignore the problem.

Also, for the use of these solutions it is necessary to know the underlying implementation, which does not promise their practical usability. For example, none of the proposed approaches provides a user interface that could allow simple management of the access control rules.

## VII. Conclusion and Future Work

The main goal of our research is to propose development process for Semantic Web applications. In order to achieve that goal, it was necessary to explore what characterizes the Semantic Web application and how it is defined. Also, it was necessary to do a review of available Semantic Web technologies and Web application development trends in order to find out are the Semantic Web technologies mature enough to be building blocks of a modern Web application. Finally, based on our hypothesis that providing general architecture and development process for all Semantic Web applications would be inadequate, we conducted an analysis of Semantic Web solutions in order to identify typical use cases. In this paper we shortly presented the methodology used throughout our research. We elaborated the results of our analysis providing definitions for the identified frequent Semantic Web application categories. As a result of our analysis we also gave explanations and generalizations for the recognized common functionalities of the Semantic Web applications. Once we have established categorization scheme, and defined basic functionalities for each of the categories, we set foundation for future work, which will consist of defining architecture for the categories and later, the development process for the Semantic Web applications.

## Acknowledgment

The presented work was funded by Croatian Ministry of Science, Education and Sports, record no. 036-0361983-2012. The authors would like to thank the funding agency for their support.

## References

[1] Abel, F., Frank, M., Henze, N., Krause, D., Plappert, D., Siehndel, P.: ‘GroupMe!-Where Semantic Web meets Web 2.0’, Lecture notes in computer science, 2007, 4825, pp. 871-878
[2] Alavi, M., Leidner, D., Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues, *MIS Quarterly*, pp. 107-136, 2001
[3] Anand, S., Mobasher, B.: ‘Intelligent techniques for web personalization’, Lecture notes in computer science, 2005, 3169, pp. 1-36
[4] Berners-Lee, T.: 'Linked data', http://www.w3.org/DesignIssues/LinkedData.html, 02.09.2010.
[5] Berners-Lee, T., Hendler, J., and Lassila, O.: ‘The semantic web’, *Scientific American*, 284, (5), pp. 34-43, 2001
[6] Bizer, C., Cyganiak, R.: ‘D2RQ-Lessons Learned’. W3C Workshop on RDF Access to Relational Databases, Cambridge, MA, USA, 2007
[7] Boiko, B., *Content management bible 2nd edition*, Wiley Publishing, Indianapolis, USA, 2005
[8] Brooks, F., No silver bullet: Essence and accidents of Software engineering, *IEEE computer*, 20, (4), pp. 10-19, 1987
[9] Clarke, C.: ‘A Resource List Management Tool for Undergraduate Students Based on Linked Open Data Principles’. 6th European Semantic Web Conference, Heraklion, Greece, 2009
[10] Conallen, J.: ‘Modeling Web application architectures with UML’, Commun. ACM, 42, (10), pp. 63-70, 1999
[11] Corcho, O., Gómez-Pérez, A., López-Cima, A., López-García, V., Suárez-Figueroa, M.: ‘ODESeW. Automatic generation of knowledge portals for Intranets and Extranets’, *Lecture Notes in Computer Science 2870*, pp. 802-817, 2003

[12] Corcho, O., López-Cima, A., Gómez-Pérez, A.: 'A platform for the development of semantic web portals'. *In: Proceedings of International Conference on Web Engineering*, , pp. 145-152 2006

[13] Ginige, A., and Murugesan, S., Web engineering: an introduction, *Multimedia, IEEE*, 8, (1), pp. 14-18, 2001

[14] Hausenblas, M., Slany, W., Ayers, D.: A performance and Scalability metric for virtual RDF graphs. *3rd Workshop on Scripting for the Semantic Web*, Innsbruck, Austria, 2007

[15] Heath, T., Motta, E.: 'Revyu. com: a Reviewing and Rating Site for the Web of Data', Lecture notes in computer science, 2007, 4825, pp. 895 – 902

[16] Heitmann, B., Transitioning Web application frameworks towards the Semantic Web, *Master's Thesis*, Universität Karlsruhe, 2007

[17] Houben, G., Barna, P., Frasincar, F., Vdovjak, R., HERA: Development of Semantic Web information systems, *Lecture notes in computer science*, pp. 529-538, 2003

[18] Jacyntho, M., Schwabe, D., Rossi, G., A Software Architecture for Structuring Complex Web Applications, *Journal of Web Engineering*, 1, (1), pp. 37-60, 2002

[19] Joo, J., Lee, S., Adoption of the Semantic Web for overcoming technical limitations of knowledge management systems, *Expert Systems With Applications*, 36, (3P2), pp. 7318-7327, 2009

[20] Kim, H., Yang, S., Song, S., Breslin, J., Kim, H.: 'Tag mediated society with scot ontology'. 6th Internatinal Semantic Web Conference, Busan, Korea, 2007

[21] Kim, H., Passant, A., Breslin, J., Scerri, S., Decker, S.: 'Review and alignment of tag ontologies for semantically-linked data in collaborative tagging spaces'. In: proceedings of, 2008, pp. 315-322

[22] Liu, J.N.K., Fuzzy Ontology Based System for Product Management and Recommendation, *International journal of computers*, Issue 3, Volume 1, pp.117-124, 2007.

[23] Mahmood, Z., A Framework for Software Engineering Education: A Group Projects Approach, *International journal of education and information technologies, Issue 3, Volume 1*, pp. 153-156, 2007

[24] Maier, R., Knowledge management systems: Information and communication technologies for knowledge management, *Springer-Verlag*, New York Inc, 2004

[25] Mika, P.: 'Flink: Semantic web technology for the extraction and analysis of social networks', Web Semantics: Science, Services and Agents on the World Wide Web, 2005, 3, (2-3), pp. 211-223

[26] Mycroft, A., Controlling Control Flow in Web Applications, *Electronic Notes in Theoretical Computer Science (ENTCS)*, 200, (3), pp. 119-131, 2008

[27] Mulvenna, M., Anand, S., Buchner, A.: 'Personalization on the net using Web mining: introduction', Communications of the ACM, 2000, 43, (8), pp. 122-125

[28] Openlink Virtuoso:Universal server platform for the real-time enterprise, http://virtuoso.openlinksw.com/.

[29] O'Reilly, T., What is Web 2.0: Design patterns and business models for the next generation of software, http://www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-Web-20.html, 02.09.2010

[30] Oren, E., Delbru, R., Decker, S.: 'Extending faceted navigation for RDF data', Lecture notes in computer science, 2006, 4273, pp. 559-572

[31] Oren, E.: *Algorithms and Components for Application Development on the Semantic Web*, National University of Ireland, 2008

[32] Pieters, K.P., A Pattern-Oriented Approach to Health; Using PAC in a Discourse of Health, *International journal of education and information technologies, Issue 2, Volume 3*, pp. 126-134, 2009

[33] Raskin, R., Pan, M.: 'Knowledge representation in the semantic web for Earth and environmental terminology (SWEET)', Computers and Geosciences, 2005, 31, (9), pp. 1119-1125

[34] Reif G., *WEESA – Web Engineering for Semantic Web Applications*. Ph.D. thesis, Technische Universität Wien, 2005

[35] Resnick, P., Varian, H., Recommender Systems, *Communications of the ACM*, 40, (3), pp. 56-58, 1997

[36] Shadbolt, N., Gibbins, N., Glaser, H., Harris, S., Schraefel, M.: 'CSAKTive Space, or how we learned to stop worrying and love the semantic Web', IEEE Intelligent Systems, 2004, 19, (3), pp. 41-47

[37] Smith, M.A., Portals: toward an application framework for interoperability, Communications of the ACM, 47, (10), pp. 93-97, 2004

[38] Stegers, R., Fekkes, P., Stuckenschmidt, H.: 'MusiDB A personalized search engine for music', Web Semantics: Science, Services and Agents on the World Wide Web, 2006, 4, (4), pp. 267-275

[39] Tokarz, K., Jedrychowski P., Using XML messages in communication between elements of the eLearning system, *International journal of education and information technologies, Issue 2, Volume 2, pp. 149-156, 2008.*

[40] Ziemer, S., Web Engineering, http://csgsc.idi.ntnu.no/2004/data/svenz/WE_csgsc.pdf, 02.09.2010.