Semantic Web Technology: The Foundation For Future Enterprise Systems

by
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Abstract

The semantic web is an extension of the current web in which data and web resources is given more meaning by incorporating metadata. The incorporation of metadata leads to an improved utilization of web resources by software applications, which will be acting on behalf of human users. In this paper we introduce the semantic web technologies, specifically RDF, RDF Schema and OWL that have been recommended by the W3C. Particularly, we encourage the Kenyan web developer to use these semantic languages in addition to HTML in their projects.

1. Introduction

The wide adoption of information and communication technology innovations has brought a lot of benefits. In particular, the World Wide Web has changed the way we work, and access information. It has placed information at our fingertips. But this information is designed for human readers. The machines that store and presents this information to us cannot understand or interpret it.

One way to change all this is to provide the information in such a way that machines can understand, so that it would be possible to develop software agents, who act on behalf of users, can carry out practical and autonomous task. This is the vision of the Semantic web as laid out by Tim Berners-Lee, James Hendler, and Ora Lassila in 2001 [3]. In their definition, they explain that the semantic web is intended to be "an extension of the current web in which information is given a well defined meaning, better enabling computers and people to work in cooperation".

The well defined meaning is added to the web by means of metadata. The metadata is given in formal standardized format which can be interpreted by machines. The W3C recommendation [16] is based on the use of Extensible Mark-up Language (XML) for syntax and Resource Description Framework (RDF) and its related vocabulary RDFS for meaning. To facilitate reasoning about meaning of resources and it trustworthiness the web ontology language OWL has been recommended.

In this paper, we will introduce these standards that are now W3C recommendations, and urge the Kenyan web developers to embrace them. The rest of the paper is organized as follows. In next section, we introduce layered approach to achieving the goal of the semantic web. Next, we look into more details the RDF concept, and the related vocabulary RDFS. We then describe in section 4 the semantic web ontology layers' language OWL. In section 5, we look at the current usage of the semantic web, and outline the theme of our effort at Strathmore University. Section 6 summarizes our belief on the usefulness of these technologies in the context of the Kenyan market. We then offer a conclusion.

2. The Semantic Web

In the current web, the content is designed for human consumption. The main focus is on documents. This is based on the concept that a document or media can link to any other document (or different media). It is difficult to find, present, access, or maintain available electronic information on the web. The languages used to create the web such as HTML tend to focus primarily on document structure and document presentation. Little or no attention is given to the representation of the meaning of the content itself, i.e. the (domain-specific) representation of the subject of the document.

The semantic web address these shortcomings by using technologies such as RDF, OWL and data centric XML. The requirements and the design issues formulated for the semantic web are implemented in the layers of technologies and standards shown in Fig. 1. According to this architecture, the semantic web is to be built in an incremental fashion.

We will introduce in this paper the main standards that have been endorsed by W3C as of Feb 2004, the Resource Description Framework (RDF) with its companion standard (RDFS) and the Web Ontology Language (OWL). The top layers Proofs and Trust are now being addressed by academic research and is outside the scope of this paper.

The semantic web ground itself on available standards for referring to entities; the Uniform Resources identifiers (URIs) [8] and encoding of character symbols i.e. Unicode [24]. For syntactical purposes, it uses web technologies like Extensible Markup Language (XML) [6], XML Schema standards [13] and XML Namespaces specification [7].

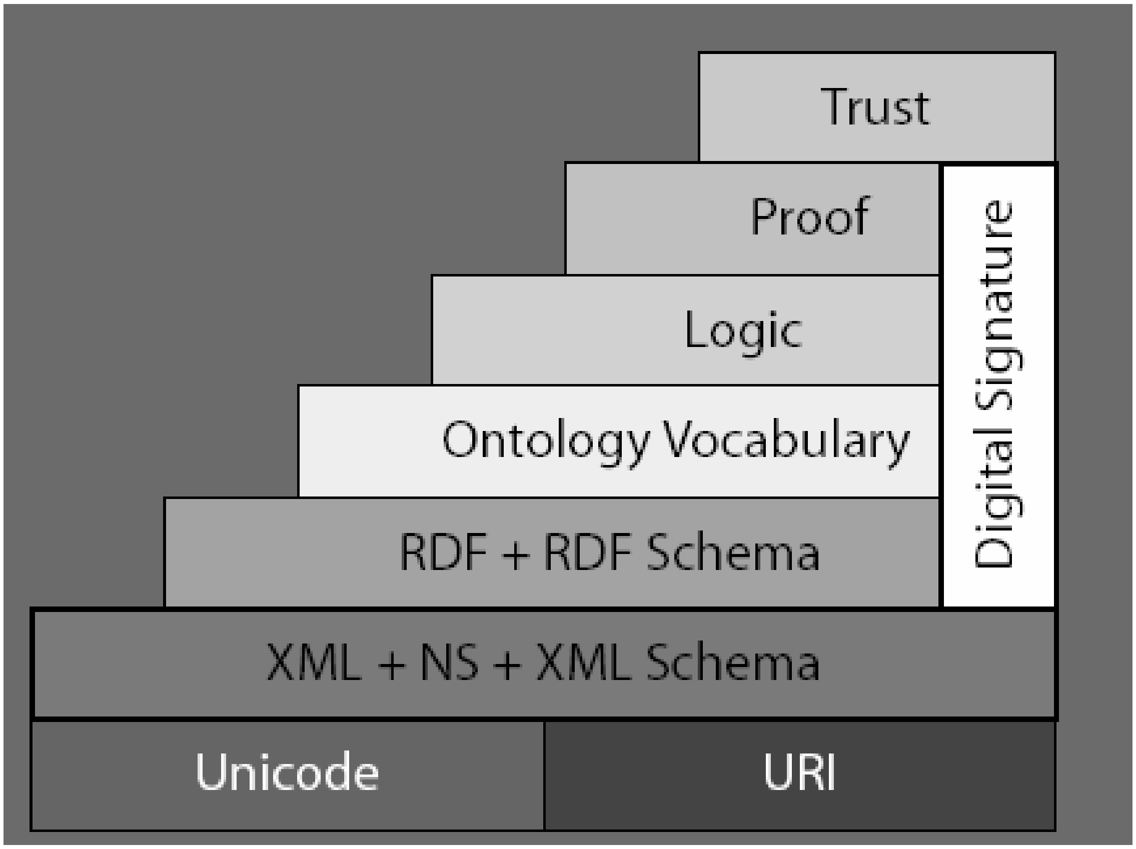

Fig. 1: The Semantic Web Layer Cake (Berners-Lee, 2000)

3. Resource Description Framework (RDF)

The semantic web aims to give meaning to resources and the cornerstone of this is the Resource Description Framework (RDF). RDF is a language for representing information about resources in the World Wide Web [20]. It is particularly intended for representing metadata about things that can be identified on the Web, even when they cannot be directly retrieved on the Web.

a. RDF data model and syntax

Resources are described in terms of properties and property values using RDF statements. RDF statements are a triple consisting of resource, property and value typically referred to as (subject, predicate, object). RDF uses URI to identify resources. The RDF specification defines a graphical representation for RDF descriptions as graphs. A description is a labelled graph with the subjects and objects as nodes and the property as an arc originating from the subject. A particular description about resource includes a number of statements, for example in Strathmore University, we know that Dr. Freddie Acosta has written a paper titled Problem Based Learning Methodology, and he has an email address as well as a home page. Figure 2 graphically depicted the scenario as an RDF graph.

The RDF specification provides a textual representation using XML syntax [2]. Other notations for serializing RDF also exist, e.g. N3 [3], Tutle [?]. The RDF/XML serialized form of the graph in figure 2 is shown in Figure 3.

b. RDF Vocabulary Description Language

The RDF vocabulary description language [8] also called RDF schema, defines a modelling language on top of RDF. RDFS is a language for defining vocabularies intended for use in RDF statements. RDF Schema vocabulary consists of classes and properties, which can be used to define term hierarchies. Properties are defined with range and domain qualifiers. The schema

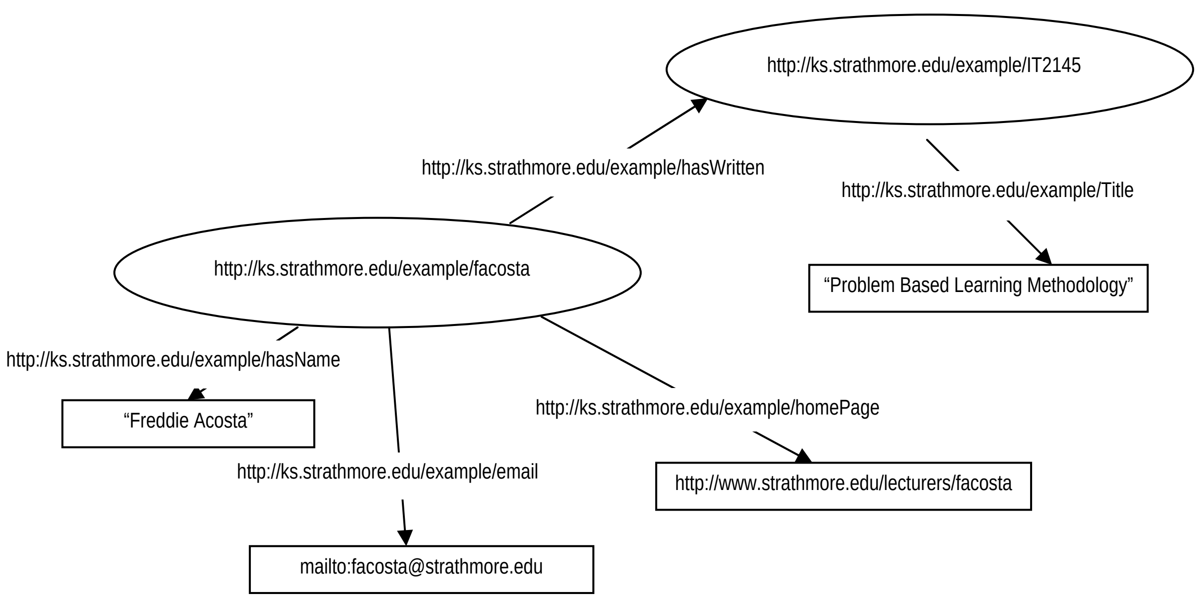

Fig. 2: An RDF graph

allows for the expressions of set memberships of individuals or objects in property and class extensions.

We can use RDFS to describe application specific RDF vocabulary. To describe classes, we make use of inbuilt RDF schema resources rdfs: Class and rdfs:subClassOf. Similarly the schema allows us to define properties (which are instances of rdfs:Property) with the corresponding global and range restrictions. Figure 4 shows the definition of classes and properties based on our example.

```
<?xml version="1.0" encoding="UTF-8"?>
<rdf:RDF        xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
            xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
            xmlns:strath="http://ks.strathmore.edu/example/">
<rdf:Description rdf:about="http://ks.strathmore.edu/example/facosta">
            <strath:homePage
rdf:resource="http://www.strathmore.edu/lecturers/facosta"/>
            <strath:hasName>Freddie Acosta</strath:hasName>
            <strath:email rdf:resource="mailto:facosta@strathmore.edu"/ >
            <strath:hasWritten rdf:resource="
http://ks.strathmore.edu/example/IT2145"/>
</rdf:Description>
<rdf:Description rdf:about="http://ks.strathmore.edu/example/IT2145">
            <strath:Title>Problem Based Learning Methodology</strath:Title>
</rdf:Description>
</rdf:RDF>
```

Fig. 3: An RDF/XML serialization of the graph of fig. 3

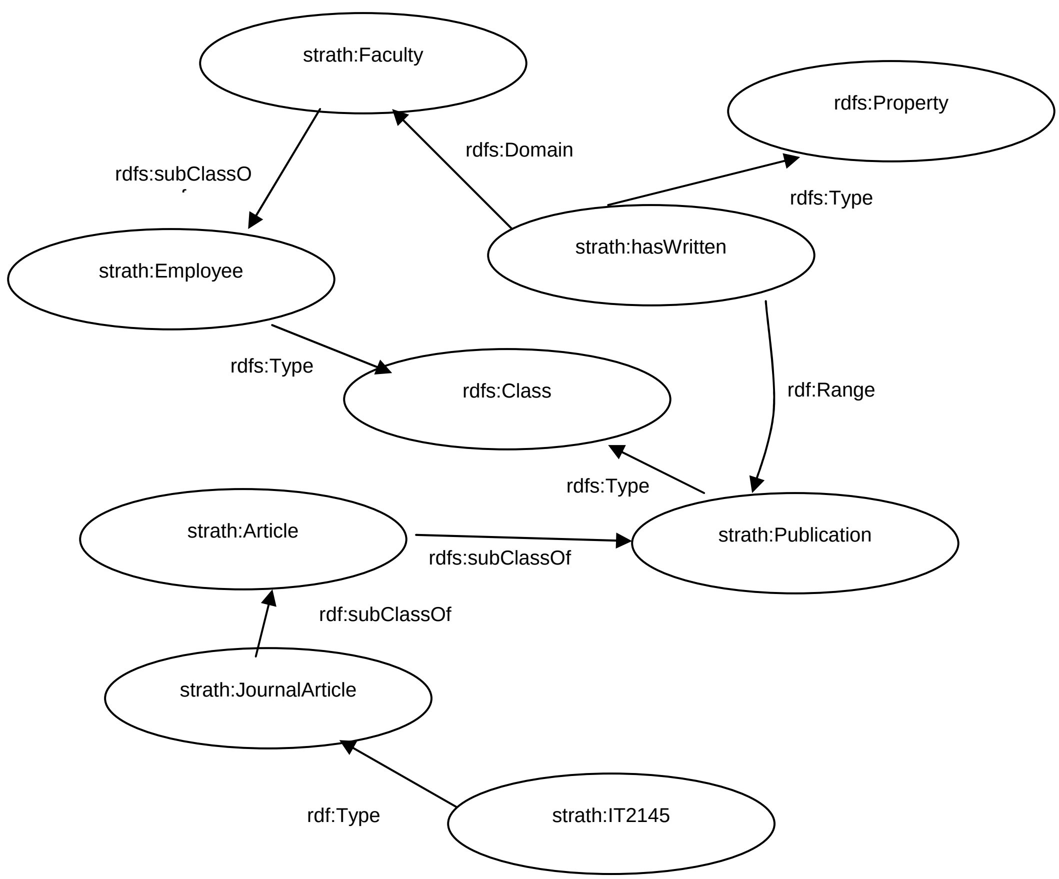

Fig. 4: RDFS Class hierarchy

4. Web Ontology Language

The expressivity of RDF and RDF Schema is deliberately very limited [21]: RDF is limited to binary ground predicates, and RDF Schema is limited to a subclass hierarchy and a property hierarchy, with domain and range definitions of these properties. Though RDF Schema provides a language for describing the vocabulary of RDF data, the requirements for a modelling language for the semantic web required a richer and more expressive vocabulary language. To come forward with such a language, the Web Ontology Working Group chose Description logics [?] as a logical basis of for an expressive ontology language. The Web Ontology language (OWL) can be considered as a particular Description Logics.

Ontology

The term ontology originated from Philosophy, where it means a description of the nature of being. Gruber [15] defines ontology as a explicit specification of a shared conceptualization. Ontologies can be viewed as models that represent an abstraction of a domain in a formal way, such that parties are able to agree on the abstraction and reuse the model in their own (web) application.

An important feature of an ontology is that you can reason about the knowledge that is modelled. Antonious & Harmelen [1] states that for ontological knowledge, we may reason about:

- Class membership. If x is an instance of class C, and C is a subclass of D, then we can infer that x is an instance of D.
- Equivalence of classes. If class A is equivalent to class B, and class B is equivalent to class C, then A is equivalent to C, too.
- Consistency. Suppose we have declared x to be an instance of the class A and that A is a subclass of B $\cap$ C, A is a subclass of D, and B and D are disjoint. Then we have an inconsistency because A should be empty, but has the instance x. This is an indication of an error in the ontology.
- Classification. If we have declared that certain property-value pairs are a sufficient condition for membership in a class A, then if an individual x satisfies such conditions, we can conclude that x must be an instance of A."

A helpful tool for reasoning is automated reasoning support. Deriving such knowledge can be made mechanical. Automated reasoning support can:

- check the consistency of the ontology and the knowledge
- check for unintended relationships between classes
- automatically classify instances in classes

Building upon RDF and RDFS is the Web Ontology Language (OWL) [12] which is a richer and more expressive vocabulary for define semantic web ontologies. OWL layers on top of that the ability to reason and make inferences about data. OWL is layered on RDF and RDF schema and uses RDF's XML syntax. OWL documents, termed OWL ontologies are RDF documents.

OWL Language

OWL builds on a rich technical tradition, of both formal research and practical implementation on ontology languages, including SHOE [17], OIL [14] and DAML+OIL [11].

Ideally, OWL would extend RDF Schema, which is consistent with the layered architecture of the semantic web. The desire to simply extend RDF schema works against obtaining more expressive powers and efficient reasoning. This prompted the Web Ontology group of the W3C to define OWL as three different sublanguages:

- OWL Full: This is a language with maximal expressiveness. It is unlikely any reasoning software to support OWL Full.
- OWL DL: OWL Description Logic is a subset of OWL full with some restrictions on the languages' expressiveness while retaining computational completeness (all conclusions are computable)
- OWL Lite: This is a subset of OWL DL that only allows for simple constraints and classification hierarchy. An advantage of this language s that it is both easier to grasp for users and easy to implement

Ontology developers are usually urged to adopt the OWL language that best suits their needs. The features of each OWL species is fully defined in [25]

5. Application of the Semantic Web

Several application of the semantic web exists. The current target area for many groups is data integration. In many companies (and across corporation), useful information is spread across many, disparate, hard to integrate databases. By encoding data in a common model we can make statements about when things are really the same (because they have the same URI. We can also use ontologies and inference to more effectively link two disparate sources of knowledge.

Semantic Web technology can be used to produce active components that use the semantic web infrastructure to offer users intelligent services. These semantic web-enabled services will support information access and e-business. This technology will provide mechanization in service identification, configuration, comparison and combination.

The semantic web technology can be used to facilitate knowledge management. Typically, useful information is scattered across an organisation in a variety of locations and stored in a variety of formats. We can use the semantic web to integrate disparate sorts of information from different places. The information can be enriched not only by the creators but also by the consumers, who just by the act of using the knowledge held would add value to it. The use of semantic web technology in knowledge management is one of the key themes of the Knowledge Systems research group at Strathmore University.

Other applications include building of social networks and intelligent web search in which the search is based on concepts and not keywords as currently implemented by search engines.

6. Discussion

The principles of the semantic web can be applied just as appropriately to the information assets of an organization. It is our belief that enterprises have a great deal to gain from the application of semantic technologies to manage and process the information they hold. We also believe that just as the corporations adopted Internet-based technology for internal networks in the form of "intranets," so too will they adopt semantic Web-based technologies to their internal systems.

These systems will require the resources to be annotated with meaning, based on the semantic web languages. To facilitate the sharing of information from diverse systems, ontologies will have to be built. As opposed to the previous scenario when you needed a domain specific language, it would be advisable to develop ontologies using the W3C recommendation, OWL. When the principles of the semantic web have gained widespread acceptance, we foresee that new applications will be based on the standards that we have described in this paper.

As a developer, in addition to the traditional web application development languages, you will need to be well versed in RDF, RDFS and OWL, on the minimum OWL Lite. Vendors will strive to make this transition for you easy. Tools are already out in the market that enables you to use RDF using your favourite programming language. A guide on such toolkits is provided in [5]. An example is the java API for RDF called Jena [9]. Jena is available for free download from (http://jena.sourceforge.net/). A well known tool for creating and editing ontology is the protégé [2] from Stanford University. Recently, an OWL plug-in was released for the software.

It is envisioned that the data held in relational and object-based database management systems should also be available for semantic web applications and DBMS developers will release products that support RDF. An example is Oracle cooperation product Oracle 10.2g [22].

7. Conclusion

The global village is here and the Kenyan developer is part of the village. We have the infrastructure that is required to support the semantic web vision. The diffusion rate of technology is now faster unlike the past. We need to seize the opportunity to help define the Kenyan content, and not wait for solutions from other parts of the world. Free open source tools are readily available, and as a developer, you should be ready to make your hands dirty. Play with these tools and do not wait for permission for the head of IT function to create ontologies. The semantic web is here. You should make it happen.

References

[1] Grigories Antoniou, & Frank van Harmelen, A Semantic Web Primer. The MIT Press, Cambridge, Massachusetts, London, England, (2004).

[2] Dave Beckett, RDF/XML Syntax Specification (Revised) W3C Recommendation 10 February 2004, W3C. [Online] at: http://www.w3.org/TR/2004/REC-rdf-syntax-grammar-20040210/

[3] Tim Berners-Lee, James Hendler, Ora Lassila, The Semantic Web, Scientific American, May 2001

[4] Tim Berners-Lee, Semantic Web Tutorial Using N3, May 20, 2003, [Online] at: www.w3.org/2000/10/swap/doc/

[5] Chris Bizer, Daniel Westphal. Developers Guide to Semantic Web Toolkits for different Programming Languages, 2006. [Online] at http://www.wiwiss.fu-berlin.de/suhl/bizer/toolkits/

[6] Tim Bray, Jean Paoli, C. M. Sperberg-McQueen, Eve Maler, François Yergeau Extensible Markup Language (XML) 1.0 (Fourth Edition) W3C Recommendation 16 August 2006, W3C. [Online] at: http://www.w3.org/TR/2006/REC-xml-20060816/

[7] Tim Bray, Dave Hollander, Andrew Layman, Richard Tobin, Namespaces in XML (Second Edition), W3C Recommendation, 16 August 2006, W3C. [Online] at: http://www.w3.org/TR/2006/REC-xml-names-20060816/

[8] Dan Brickley, R.V. Guha, RDF Vocabulary Description Language 1.0: RDF Schema W3C Recommendation 10 February 2004, W3C. [Online] at: http://www.w3.org/TR/2004/REC-rdf-schema-20040210/

[9] Jeremy J. Carroll, Ian Dickinson, Chris Dollin, Dave Reynolds, Andy Seaborne, and Kevin Wilkinson. Jena: Implementing the semantic web recommendations. Proceedings of the 13th World Wide Web Conference, 2004.

[10] Dan Connolly, Naming and Addressing: URIs, URLs, ... W3C, July 9, 2002, [Online] at: www.w3.org/Addressing/.

[11] Dan Connolly, Frank van Harmelen, Ian Horrocks, Deborah L. McGuinness, Lynn Andrea Stein, DAML+OIL (March 2001) Reference Description, W3C Note, December 18, 2001. [Online] at: http://www.w3.org/TR/2001/NOTE-daml+oil-reference-20011218.

[12] Mike Dean and Guus Schreiber OWL Web Ontology Language Reference, W3C Recommendation, 10 February 2004, http://www.w3.org/TR/2004/REC-owl-ref-20040210/. [Online] at: http://www.w3.org/TR/owl-ref/

[13] David C. Fallside, Priscilla Walmsley XML Schema Part 0: Primer Second Edition, W3C Recommendation 28 October 2004, W3C. [Online] at: http://www.w3.org/TR/xmlschema-0/

[14] Dieter Fensel, Frank van Harmelen, Ian Horrocks, Deborah L. McGuinness, and Peter F. Patel-Schneider. OIL: An ontology infrastructure for the semantic web. IEEE Intelligent Systems, 16(2):38–45, 2001.

[15] Thomas R. Gruber, 1993. A Translation Approach to Portable Ontology Specifications, Knowledge Acquisition, Vol. 5, No. 2, pp 199–220.

[16] Patrick Hayes, RDF Semantics W3C Recommendation 10 February 2004, W3C. [Online] at: http://www.w3.org/TR/2004/REC-rdf-mt-20040210/

[17] Jeff Heflin, James Hendler, and Sean Luke. SHOE: A Knowledge Representation Language for Internet Applications. Technical Report CS-TR-4078, University of Maryland, Department of Computer Science, 1999.

[18] Ivan Herman, Semantic Web Activity, 2006 W3C. [Online] at: http://www.w3.org/2001/sw/

[19] Graham Klyne and Jeremy J. Carroll, Resource Description Framework (RDF): Concepts and Abstract Syntax, Editors, W3C Recommendation, 10 February 2004, W3C. [Online] at: http://www.w3.org/TR/rdf-concepts/

[20] Frank Manola & Eric Miller (Eds.) 2004. RDF Primer. W3C Recommendation 10 February 2004, W3C. [Online] at: http://www.w3.org/TR/2004/REC-rdf-primer-20040210/

[21] Brian. McBride, The Resource Description Framework (RDF) and its Vocabulary Description Language RDFS, in: The Handbook on Ontologies in Information Systems, S. Staab, R. Studer (eds.), Springer Verlag, 2003.

[22] Oracle Press Release July 11, 2005 http://www.oracle.com/corporate/press/2005_jul/isv10gr2l.html

[23] Peter F. Patel-Schneider, Patrick Hayes, Ian Horrocks, OWL Web Ontology Language, Semantics and Abstract Syntax , W3C Recommendation 10 February 2004, W3C. [Online] at: http://www.w3.org/TR/owl-semantics/

[24] The Unicode® Standard: A Technical Introduction, 05 September 2006, [Online] at: http://www.unicode.org/unicode/standard/principles.html

[25] Deborah L. McGuinness and Frank van Harmelen, OWL Web Ontology Language Overview, W3C Recommendation, 10 February 2004, .W3C [Online] at http://www.w3.org/TR/owl-features/

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