Design and Development of Semantic Web Information System (WIS) for Virtual University of Pakistan

Amjad Farooq, M. Junaid Arshad, Syed Ahsan, M. Shahbaz, M. Aslam, Humaira Naeem

Department of Computer Science and Engineering, UET, Lahore-Pakistan
amjadfarooq@uet.edu.pk

Abstract: Semantic web is an extension of current web which defines the meaning of information in such a way so that it can be understandable by the machines and thus machines can process the information and perform reasoning on that information. With the current web, the meanings or semantics of information on the web is only understandable to the human beings whereas the basic purpose of semantic web is to make web pages not only human as well as machine understandable. The need for design methodology was considered at a time when semantic applications were developed in an ad-hoc manner with no systematic approach or methodology used to add semantics at implementation level either using manual or automatic approach. In this paper, we have critically reviewed existing design methodologies of semantic web applications and compared these methodologies based on various attributes and found out their strengths and weaknesses. In this paper, we have proposed a design methodology for semantic web information system and validate it by using Virtual University web application as a case study.

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1. Introduction

The semantic web is an extension of current web which defines the meaning of information in such a way so that it can be understandable by the machines and the information is defined such that it remains usable not only for machines but also for human beings. The major difference between current web and semantic web is that the current web is a huge distributed hypertext system which is a collection of interconnected documents whereas semantic web is a huge distributed knowledge based system as the information becomes knowledge after adding semantic annotations.

The development of complex web applications and the acceptance of internet have driven the on-going demand for new and better way for the design and development of web applications. The development of complex web applications requires a disciplined approach which uses software engineering principles. Such disciplined approach is called design methodology. The design methodology tells in a systematic way how to do each steps of software development life cycle model whereas SDLC lists only the steps required to develop an application. These design methodologies integrate semantic annotations into web engineering method by defining semantic annotations at design level. The need of design methodology was considered at a time when semantic applications were developed in an ad-hoc manner with no systematic approach or methodology and used to add semantics at implementation level either using manual approach or automatic approach. Using a design methodology, modification and maintenance of an application requires less effort and time.

The paper is organized as follows. Section 2 briefly explains some of the existing design methodologies of semantic web applications. The strengths and weaknesses of these design methods have also been given in same section. The comparison of these design methods based on various parameters is given in Section 3. Our proposed design methodology is given in Section 4. In Section 5, our proposed design methodology is validated via a case study. Finally, results, conclusion and future work has been given in Section 6.

2. Literature Survey

In the literature survey, we have found three types of approaches for the design and development of semantic web applications: Manual approach, Automatic approach and Web engineering approach/Design Methodology (Ambler, 2002). The earlier annotation systems such as SHOE, MindSwap and CREAM were based on manual approach and used to add semantics to HTML pages manually but this manual approach leads to many syntax errors by human beings and it was a tedious and cumbersome task. Then automatic approaches were introduced which uses graphical user interface to add semantic annotation to web sites (Marcos, 2006). These graphical user interfaces are SHOE Knowledge Annotator, SMORE (Semantic Markup, Ontology and RDF editor) and CREAM. From these GUI,

SHOE Knowledge Annotator and SMORE are suitable for annotating static web sites whereas CREAM is suitable for dynamic web sites. Both of these approaches (manual and automatic) had disadvantage that semantic annotations were defined at implementation level and it requires considerable effort to generate semantic contents after the web site is fully implemented. This problem can be solved by integrating the annotation process into web engineering method which defines the annotation at design level (Jaeger et al., 2005). Web engineering approach or design method is a disciplined and systematic approach which uses engineering principles for the development, deployment and maintenance of web applications.

Table 1: Comparison of existing Semantic-web applications design methods

	WSDM	**HERA**	**SHDM**	**OntoWeaver**	**OntoWebber**	**SEAL**
Phases/Modules	5	2	5	4	5	9
Methodology	Audience driven Web-engineering	Model driven Web-engineering	Model driven Web-engineering	Model driven Web-engineering	Model driven Web-engineering	Web-engineering
Extension	WSDM (Web Site Design Method)	NA	OOHDM (Object-oriented hypermedia design)	NA	NA	NA
Number of layers supported if a Layered Architecture	×	3	4	×	4	×
Suitable for web application	Localized websites	Semantic WIS / Customized web applications	Semantic WIS	Customized data-intensive web applications	Customized web applications/ data intensive applications/ semantic web community portals	Semantic web portals, Information Retrieval system
Supports localization of web site	√	×	×	×	×	×
Semantic Annotation process starts from	Object chunk (a data model which models the necessary information that are needed to fulfill the requirement of that elementary task)	RDF	UML like class diagram which are later mapped to RDF/XML format	RDF	RDF	RDF generator which generates RDF statements from the internal knowledge warehouse
Semantic web languages	OWL	RDF, RDF(S), RQL	ORM, DAML+OIL, OWL, RDF, RDFS, RQL	RDF	RDF, DAML+OIL	RDF
Supports different types of user	√	×	√	√	√	×
Classification of users	√	×	×	×	×	×
Supports personalization of presentation based on user preferences a design level	×	√	×	√	√	√
Support pre-defined customization or static customization	NA	√	√	×	√	NA
Support dynamic customization	NA	×	×	√	×	NA
	NA	NA	NA	√	√	NA
	NA	NA	×	NA	√	NA
	NA	NA	×	NA	NA	√
	NA	NA	×	NA	NA	√
	NA	NA	Sesame, BOR	JESS	NA	OntoBroker

2.1 WSDM (Web Site Design Method)

WSDM was one of the first web design method developed in 1998 by De Troyer and Leune. This methodology is an extension of WSDM (Web Site Design Method) of traditional web-based applications. It is an audience driven design methodology for the development of semantic web applications as it takes into account requirements of different types of users. The main objective of WSDM design method was to cerate different versions of a web site for different community or locality in order to attract more customers as different localities and communities have their own languages, standards and cultural attributes (Mark and Kevin, 2007).

2.2 SHDM (Semantic Hypermedia Design Method)

SHDM is a model-driven design method to develop semantic web application. It is an extension of OOHDM (Object-oriented design method) therefore uses object oriented paradigm and then uses ontologies to add annotation (semantic content) to the web application (Bruijn et al., 2006). It has five different phases: Requirement gathering, conceptual design, navigational design, abstract interface design and implementation.

2.3 HERA

Hera is a design methodology for the design of semantic WIS (Web Information System). WIS is an information system which uses web technologies to retrieve information from the web and deliver it to users or other information system. It is a model driven design methodology which retrieves data from different data sources and presents the retrieved data in different format to different types of users based on their preferences as it supports customization of web sites (Hepp et al., 2006).

2.4 OntoWeaver

OntoWeaver is an ontology-driven design methodology for creating and maintaining customized web applications. Customization of web site means presenting the contents of a web site according to needs or preferences of users and different types of devices used. It is a model-driven methodology which explicitly specifies different site specification at conceptual level and then uses JESS inference engine which performs inferencing on site models to create web site in desired format according to the preferences of users at run time. The declarative nature of site specification enables designer to manage and maintain web application at conceptual level (Bruijn et al., 2006).

2.5 OntoWebber

OntoWebber is a model-driven ontology based design methodology for building data-intensive web site and web portal. In most of the previous method, design was hard-coded in HTML, ASP, JSP, etc but this method uses re-usable components such as ontologies to design web site making the integration and maintenance of heterogeneous data sources more manageable than other methods. OntoWebber uses layered architecture consisting of 4 layers.

2.6 SEAL (Framework for SEmantic portAL)

SEAL is a framework for developing semantic web portals using ontologies and information retrieval concepts such as semantic browsing and semantic ranking for semantic sharing of knowledge on the web portal between human and software agents. The architecture of SEAL consists of various modules such as knowledge warehouse, OntoBroker, RDF generator, Template module, Navigation module, Query module, Semantic personalization module, semantic ranking and Web server. It supports three types of agents: software agents, community users and general users (Murthy et al., 2006). The software agents process information on the web portal using RDF Crawler.

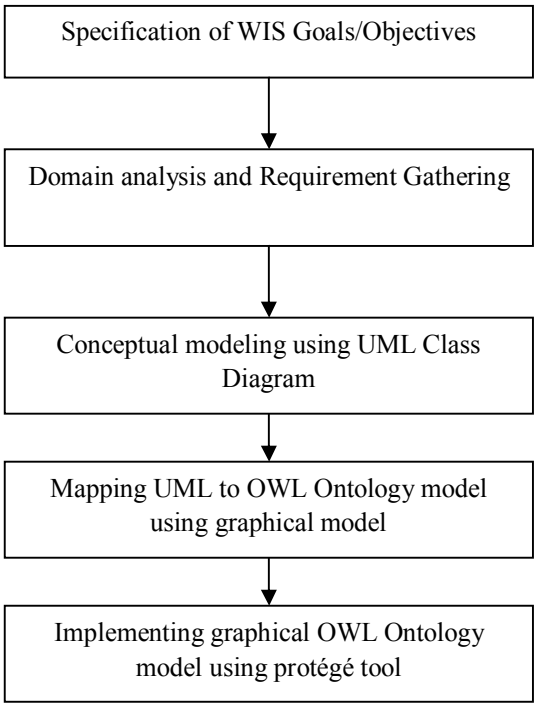

Fig. 1: Phases of proposed design methodology

3. Proposed Design Methodology

3.1 Phases of proposed design methodology (Fig. 1)

i) Specification of WIS (Web Information System) Goals/Objectives
ii) Domain Analysis and Requirement Gathering
iii) Conceptual modeling using UML Class Diagram

iv) Mapping UML to OWL Ontology model using graphical model
v) Implementing graphical OWL Ontology model using protégé tool

i) Specification of WIS (Web Information System) Goals/Objectives: This is the first phase of our proposed design methodology. The purpose of this phase is to specify Goals/Objectives of web application. For example, we can formulate specification of a web application as given below. As an example, we have taken Virtual University web site.

Goals/Objectives: "The purpose of this web information system is to provide a virtual class environment to registered student through which they can view course contents, take online video lectures, post their queries on discussion board, received answers of their queries from instructors, view uploaded assignments given by instructor, upload their solution, view grade book, view latest announcements by university".

ii) Domain Analysis and Requirement Gathering: In this phase, detailed analysis of domain is performed and requirements will be gathered from user which will help in building conceptual model which will be given in next phase.

In this phase, different types of users interacting with WIS are identified and for each type of user, the different requirements are formulated. The requirements are formulated informally in natural language statements.

In our example web site, there are different types of users such as Students, Faculty members, Visitors and IT support peoples.

iii) Conceptual modeling using UML Class Diagram: This is the third phase of proposed design methodology. In this phase, we identify different classes, attributes of classes and relationships that exist between different classes and then construct the UML class diagram. Domain analysis and requirement gathering phase helps in identifying all constructs of UML model. UML is a graphical representation model and is used to model the domain of interest.

iv) Mapping UML to OWL Ontology model using graphical model: In this phase we have given the rules for transforming UML model to OWL Ontology model.

The following Table 2 gives the equivalent OWL terms/concepts and constructs of UML.

There are some additional constructs and concepts of OWL which are not present in UML.

3.2 Properties Restrictions

a) Value restriction: owl:hasValue (defines a specific value a property must have)
b) Universal Quantifier: owl:allValuesFrom (all values of this property must come from this class only)
c) Existential Quantifier: owl:someValuesFrom (at least one value of this property must come from this class, other values can come from other classes)

OWL Ontology Model: The following OWL ontology model is constructed after applying rules on UML model to transform it into OWL ontology model (Fig. 2).

Table 2: UML concepts vs. OWL concepts

UML concepts	OWL concepts	OWL constructs
Classes	Classes/Concepts	owl:Class
Inheritance/Hierarchy	Taxonomy (subClassOf)	rdfs:subClassOf
Properties/Attributes	Data properties	owl:DatatypeProperty
Relationships among Objects/Individuals (association, composition, aggregation)	Object properties	owl:ObjectProperty
Classes for which relationship exists such as composition and aggregation	Domain of property	rdfs:domain
Classes for which relationship exists such as composition and aggregation	Range of property	rdfs:range
(Multiplicity/Cardinality)	Cardinality constraints Max cardinality Max cardinality Exact cardinality	owl:minCardinality owl:maxCardinality owl:cardinality

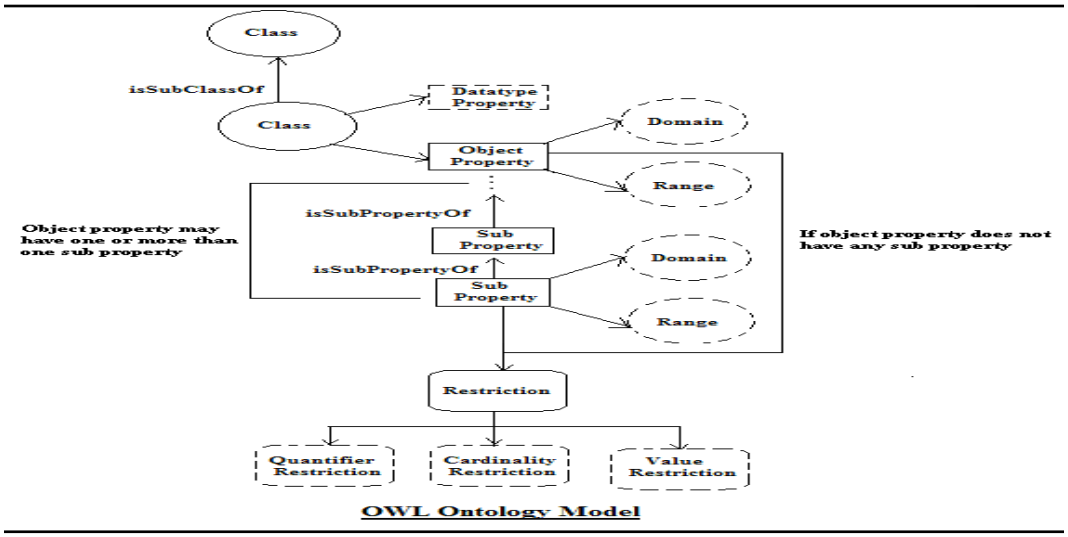

Fig. 2: OWL ontology model

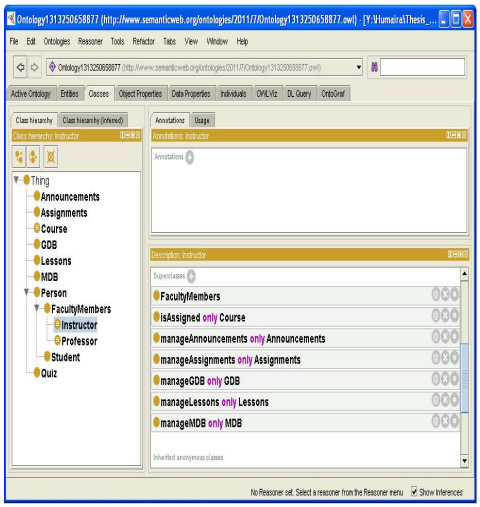

Fig. 3: Ontology class construction

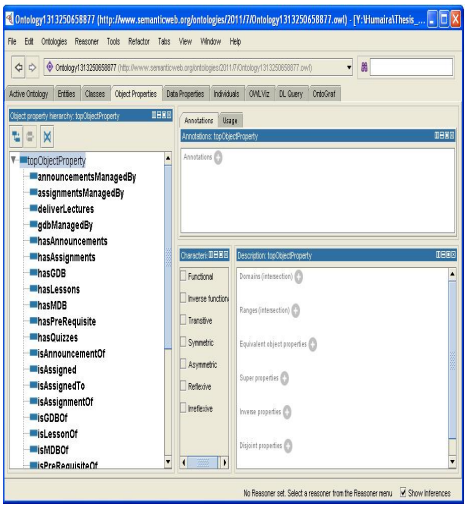

Fig. 5: Ontology object properties construction

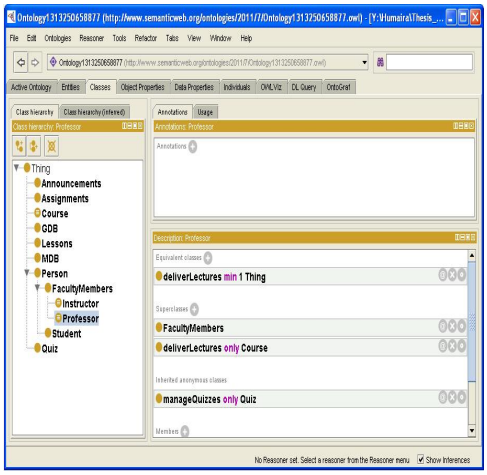

Fig. 4: Ontology class constraints

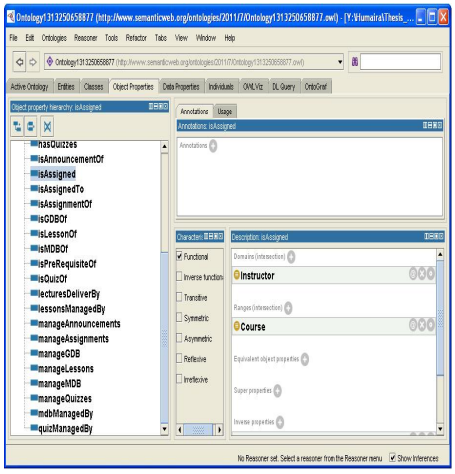

Fig. 6: Ontology object properties constraints

4. Case Study

In this section, we have used Virtual University web site as a case to demonstrate the capability of design method to the design and development of semantic web information system for Virtual University of Pakistan. The purpose of this web information system is to provide a virtual class environment to registered student through which they can view course contents, take online video lectures, post their queries on discussion board, received answers of their queries from instructors, view uploaded assignments given by instructor, upload their solution, view grade book, view latest announcements by university".

We have identified different classes, their attributes and relationships that exist between these classes which will help in developing domain model. Some screen snaps are given below (Fig. 3 – Fig. 6).

5. Results: Discussions and Analysis

In Our case study, we have applied our design methodology on VULMS (Virtual University Learning Management System) of Faculty members. Faculty members have access rights to the course assigned to them. They are responsible for managing all activities of assigned course such as managing assignments, quizzes, MDB (Moderated Discussion Board), GDB (Graded Discussion Board), announcements, lessons. After developing the system, it has been validated through W3C, Validation service. Through results we are confirmed the correctness and completeness of the system.

6. Conclusion and Future Work

Various design engineering methodologies have been proposed for the design and development of semantic web applications. These methodologies differ from the design methods of traditional web-based application as the design methods for semantic web applications focus on addition of semantics to web applications by enabling machines so that they can understand and process the information. Most of the design methods for semantic web applications are the extensions of traditional methods of web-based applications. These design methods have no guarantee that all software development problems will be solved but they attempt to design and develop semantic web application by applying design techniques and rules. The different methodologies that we reviewed are WSDM, HERA, SHDM, OntoWebber, OntoWeaver, SEAL, SFrameWeb, WebML, OO-H, WESSA, UWE and SW-OODM.

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