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Visualization Techniques in Semantic Learning Based on Case Studies

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Abstract **– From traditional classroom teaching to e-learning through Learning Management Systems or Intelligent Tutoring Systems, there has been a paradigm shift from teacher centric models to learner centric models of learning. Next step is towards bringing interoperability and reusability among these applications. Semantic web has played an important role in designing such applications by either extending already existing applications to semantic web or creating new applications that are completely semantic web based. Use of visualization techniques is a step further towards increasing the efficiency of applications by providing visuals of the knowledge as these are more effective in expressing an idea. This paper compares and analyses two semantic web based learning frameworks that are functionally different but both use some kind of visualizations in representing knowledge structures. First model given by Zorica Bogdanović et al aims at improving searchability and browsability of educational resources in a Learning Management System by extending them into semantic web through its core logic component and using the visualization tools to create visualization of data and enrich it with information gathered from social networks and semantic databases. Second model is a conceptual browser named Conzilla developed by Naeve et al. which is totally based in semantic web and represents the knowledge in the form of context maps connected to each other through concepts. Although purpose and functionality of both these applications is quite different, both of them attempt to utilize sematic web characteristics as well as visualization tools in representing knowledge.**

Keywords **– Concept Browser, Learning Management Systems, Ontology, Semantic Web, Visualization Techniques**.

I. Introduction

E-learning is not concerned just with providing easy access to learning resources anytime, anywhere but also with providing features like personal definition of learning goals. Major advantage of these applications over traditional teaching methods is the availability of learning resources from vast reservoir available on web round the clock and facility to the learner to learn at his/her own pace. Over the years these applications have been successfully adopted by learners as well as organizations, however, web is growing day by day with millions of pages added to it every day. This makes it difficult for these applications to search and navigate effectively within this distributed structure of knowledge. Hence, scope of these applications is becoming narrow day by day as they are not capable of tapping the potential of this vast reservoir of information. Moreover, eLearning applications running on the web follow different set of standards. Hence two of the main benefits of interoperability and reusability offered by the web are not fully utilized by these applications [10]. Semantic web is the answer to these limitations where knowledge is represented in structured or semi-structured form and systems perform complex tasks of searching and navigation for its users [1]. E learning applications based on semantic web can effectively tap the potential of semantic structure of the web and give the learner what he wants with more precision. Another important feature that can further enhance the capabilities of e learning applications is the visualization of learning objects. Visualization techniques help learner in better understanding of the domain he intends to study and an appropriate presentation and visualization of information can strongly influence the learning experience by allowing learners to explore the subject effectively[4]. These techniques can be used in different ways. The concepts learner wants to learn can be presented in the form of maps which provide an overview of the subject he wants to study. Knowledge about the domain of study can also be represented as a map helping the learner gain an overview of his current level of knowledge and showing the prospective direction.

II. Review of Literature

With the success of web, many organizations and research groups are focusing on the issues of reusability and interoperability among existing Learning Management Systems (LMS) or Intelligent Tutoring Systems (ITS)[17]. Many organizations have come up with standard architectures and formats for e-learning platforms. Shareable Content Object Model (SCORM)[17] by Advanced Distributed Learning(ADL) provides a reference model that includes standards for content aggregation as well as a run-time environment. Another key player Instructional Management Systems (IMS) provides a set of basic as well as enterprise standard which specifies how an LMS should exchange messages regarding management of courses and students, such as tracking, assessment etc[6].

Power of semantic web comes from the data that is annotated with both subjective as well as objective metadata [13]. This can be done using one or several metadata specifications or standards that define terms to be used in the metadata expressions. Two examples of metadata specifications for objective metadata are Dublin Core terms [19] and IEEE/LOM[6]. For subjective metadata, there is one initiative, the MOAT project (Meaning of A Tag) [16]. Another project capable of expressing subjective metadata using RDF technology is Annotea. [7]

Resource Data Framework (RDF) which is a set of statements that are facts about a resource like title, description, creation date, or a relation to another resource, is an important pillar in semantic web[9]. Vocabulary, a set of URIs used for representing predicates, are used for reusability need to be formalized before using. To formalize a vocabulary RDF Schema (RDFS)[3] or Web Ontology Language (OWL) can be used[14].

Many e-learning frameworks that are based on semantic web are being developed. An e-learning scenario given by Stojanovic et al. [18] concentrates on ontologies for e-learning objects. Fayed Ghaleb et al.[5] proposed another model focusing on the RDF data model and OWL. This model allows E-learning content to be created, annotated, shared and discussed, supplying resources such as lecture notes, course description etc., useful URL links along with exercises and quizzes for evaluation of the student knowledge. It has been demonstrated using different type of courses taught in Qatar University.

Visualizing learning resources in an effective manner helps learners to better understand the topic he wants to study. The visualization represents knowledge about the domain of study and can be used by the learners as a map, helping them gain an overview of their current level of knowledge and showing them potential avenues of advance[4]. Appropriate visual encoding should be selected by taking the purpose of visualization and human perception system into consideration.[15]. [4] discusses current approaches for data browsing and visualization stating the importance of both the visual and textual representation. “Text allows fine grained analysis, while visual browsing provides insight into the structure of a domain and allows for the bigger picture to be seen.”[4]. Both approaches can be combined for effective presentation of data.

e-learning framework designed by Zorica Bogdanović et al [20] is the first case study of this paper and it aims at improving searchability and browsability of educational resources in a LMS by applying semantic annotation to educational resources, actors, and other concepts, and using the semantics to visualize data and enrich it with information gathered from social networks and semantic databases. Another case study is a conceptual browser named Conzilla[11] developed by Naeve et al. Conzilla is more general application that aims to create an overview of information without losing depth. Overview and depth are achieved by creating maps which display concepts and their relations at different level of detail. It also provides total separation of the context from its content.

III. Objectives

Over the past few years many researchers have proposed different models of e learning applications which use different tools of semantic web to structure and use annotated data. For the purpose of comparing and analyzing in this paper, two models, first provided by Zorica Bogdanović et al and another Conzilla which is a concept browser[11] given by Naeve et al are taken as case studies. Objectives of this study can be listed as follows -

1. To study the architecture and various components of the above two models.
2. To analyse these models on various parameters like purpose of use, technology used, formats used for annotating with metadata subjective as well as objective, creation of data repositories and knowledge structures etc.
3. To study how these applications provide reusability and interoperability of the learning objects.
4. Both the case studies taken in this paper utilize visualization techniques to enhance the learning experience. So, another objective is to see how visualization techniques can be used for efficient learning.

IV. Zorica Bogdanović’s Model [20]

This model aims at improving performance of existing LMS in terms of searching and browsing by performing semantic annotation of educational materials and related concepts. It also uses the structure of dependent services to extend the functionalities of the LMS with which it is used. This model provides scope for formulation of simple as well as advanced search queries along with visualizations of results, domain structure and adaptation of results according to students’ interests. A generic expendable ontology is used to store and use RDF data and educational and supporting services are provided based on that ontology.

A. Ontology

As this model is based on the domain of a learning management system(LMS) which deals with different kinds of learning resources and concepts like teachers, students, activities, etc., an ontology named SEOF (Simple Educational Ontology Framework) is created to represent all these resources and concepts. This framework represents first iteration of this ontology leaving the scope for further expansion and refinement. SEOF uses a general and abstract ontology development tool by utilizing UML (Unified Modeling Language) class diagrams.

Most of the SEOF concepts and their relations are shown in fig. 1.

Concepts included in SEOF are educational resources, classes, activities, teachers and students and topic. All the sets can be expanded according to the functionalities of the learning management system used. Educational Resources class uses Dublin Core set of metadata attributes to ensure interoperability. With all educational resources annotated and other concepts described and stored in some kind of a repository, the learners can perform advanced search and browse operations. If learners want to familiarize with the structure of a domain of study, a visualization of topics, related resources, activities and classes can be presented. Basic searching can be performed on the Dublin Core attributes, while advanced queries can define required values for attributes and relations.

B. Semantic services

Following the design and serialization of the ontology used, instances of defined classes are created and stored in a repository. External entities can access, read, and change the repository through the core logic component, shown in fig. 2.

Semantic services are represented using modular structure. Repository contains metadata about the resources and concepts that are part of database of the LMS. Core is independent of any LMS and communicates with them through modules, plug-ins or software supported by various LMSes to access their content. It can also integrate with existing semantic systems, services and social networks to allow semantic enrichment of internal resources, annotation of external resources, and acquiring personal information about students. LMSes communicate with the core through APIs using following five modules -

Integration module integrates resources from LMS and their metadata in repository. It keeps track of any changes made to resources, updating the repository as needed.

Profiling module gathers information about students and their activities.

Display module integrates into existing interface components of the LMS and presents the relevant metadata at all appropriate locations.

Browsing module uses the information from the repository for advanced searching and browsing functionalities of internal and external resources directly within the LMS.

Visualization module enables visualizations of the structure of the domain and of instances and their relations.

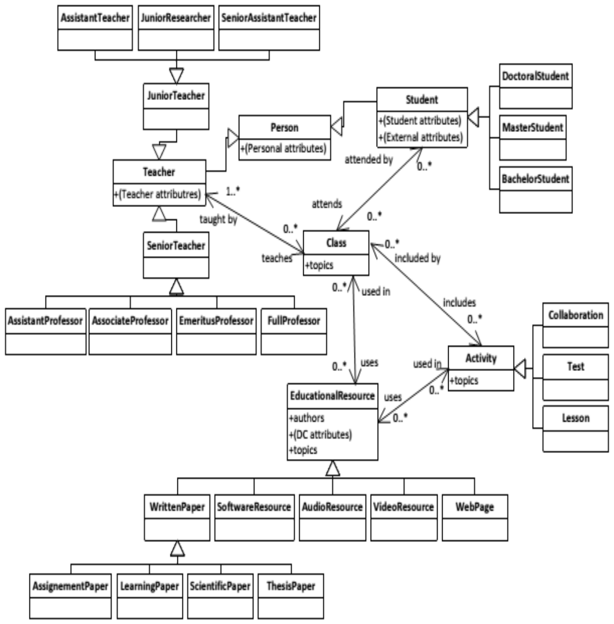

Fig.1. SEOF concepts and relations

Source: [20]

Services such as DBPedia can be used for semantic enrichment by retrieving relations between concepts that do not exist within the proposed ontology. Core system also provides an interface for system management by teachers or administrators, allowing them to add, remove, or change metadata entries, configure the modules that integrate with external systems and change other settings. If the LMS is incapable of supporting some or all of the described modules, the core system also allows direct access to students through a separate interface.

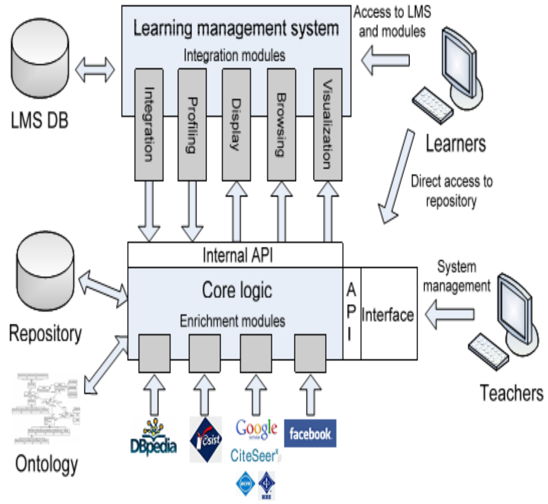

Fig. 2: Integration of LMS, ontologies and Semantic web services

Source: [20]

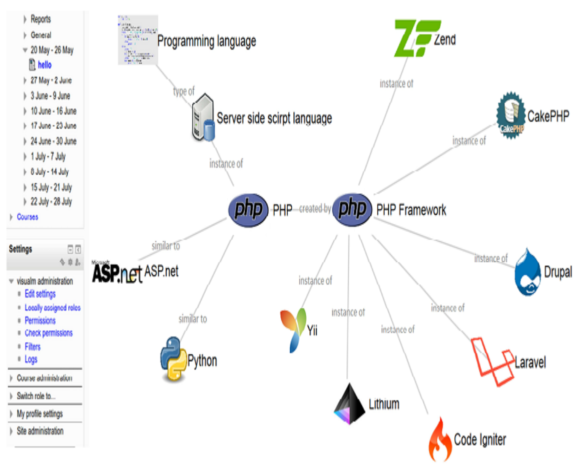

Fig. 3: Visualization of topics

Source: [20]

C. Implementation

Modular architecture allows separation between components that gather data, integrate and store it, and generate its representations. Hence, different modules can be developed and implemented independently. This framework makes use of many independent components already developed and used at University of Belgrade. The visualizations were developed using the freely available D3 library [2]. Example visualization shown in fig. 3 uses some specific metadata fields to display relations between the topics. The student can select a starting topic either through a resource tagged with that topic, or by searching

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through available topics. By clicking on a topic, all available related resources are displayed, along with the option to shift focus to that topic.

V. CONZILLA [11]

Conzilla is a concept browser used to design and present knowledge structures in the form of context-maps. These maps contain visual representation of different concepts and concept relations. It can also act as a complete RDF editor which combines graph and form-based manipulation of RDF-graphs. In addition to this, it serves as a collaboration tool for some modeling techniques like various UML-dialects. Other purposes of this concept browser are creating information according to various metadata standards, supporting customized presentations of existing information without duplication or modification of information sources. Concepts can be reused and any number of context maps can be connected and gradually expanded, hence supporting ever growing network of knowledge. Content describing these concepts is stored separately to increase usability of the content.

A. Architecture

Conzilla is an application developed using Java and RDF is used at the backend. It can either work as standalone application or as an applet in a web browser. It allows information and content to be tied to specific concepts and concept-relations.

Basic architecture of Conzilla involves -

1. Static representation of concepts and context-maps for storing and transmitting
2. An application programming interface (API) for working with concepts and context–maps

Figure 4 shows a diagram containing representation of various components of Conzilla as a context map.

B. Context maps

Interface of Conzilla is used to browse context maps or inspect concepts and concept relations displayed as context maps. Context maps consist of sets of layout resources that give graphical appearance to concepts or concept-relations. These are designed using ULM, a version of the Unified Modeling Language (UML) and support the creation of class, activity, use-case, and process diagrams. These maps can be surfed, viewed and browsed like normal web. More than one maps can be connected to each other either horizontally by using the same concept in different maps or vertically by going into the details of a concept providing a detailed map. A context-map may be built in a single piece or it can be combination of layers(where one layer can contain basic information and other the advanced one) and contributions(anyone can contribute to a context-map by including additional concepts or concept-relations, or by providing additional metadata through contributions panel).

Users can navigate between different context maps.

C. Editing a Context Map

Context maps are edited in sessions. These sessions specify containers for storing concepts and concepts-relations along with graphics and style information. Same context map can be opened and edited in different sessions in different containers to support collaboration. Although anybody can open and surf the context maps, editing can be done only according to the privileges of the session.

D. Context Map Design

In Conzilla, information about a concept or concept-relation is expressed in RDF. This information is separated from its graphical layout, and can reside in several RDF graphs. Designing of the context maps is done in three layers - information, presentation and style layer.

Information Layer

The information in this layer is made up of statements around resources expressed in RDF. Concept is constituted of a subgraph of RDF-statements centered around a specific RDF-resource and concept-relation is constituted of a subgraph of RDF-statements centered around the reification of a specific RDF statement. The information in this layer may follow a schema, a standard or be locally defined depending on the domain and the user.

Presentation Layer

This layer consists of maps of concepts and concept-relations presented by boxes and lines. Labels within the box and on the side of the line are extracted from the information layer. Concept and concept relations are not bound to any specific context map but are included in it via layouts which contain information like position, size, text-alignment, visibility etc. about these elements. A special kind of layout, which groups other layouts, is used for creating context-map layers.

Style Layer

A style describes the appearance of boxes and lines in the form of line type, line width, text alignment etc. used. Local style is applied to a specific layout of a given resource. A global class style is applied to a RDF Class or a RDF Property. A global instance style is applied to a specific resource, independently of context. If a local style and a global style are simultaneously relevant, then the local style takes precedence. Conzilla also offers a "fallback style" which applies if there is no other style.

It is possible to interact with concepts and concept-relations in three different ways(see fig. 4).

Surfing – Through hyperlinks on concepts and concept-relations which connect them to other context-maps.

Viewing Content **-** As concept browser separates content from its context, content components can be associated with concepts or concept relations in the form of explanations, examples, motivations, discussions etc in a particular map and are not visible on that concept in any other context map.

Inspecting - Metadata inspector in Conzilla provides complete description of the particular component. Conzilla provides some metadata-forms like Dublin Core, LOM and FOAF by default and the Formulator application of the SHAME framework can be used to create new metadata-forms or reuse parts from established standards / schemas.

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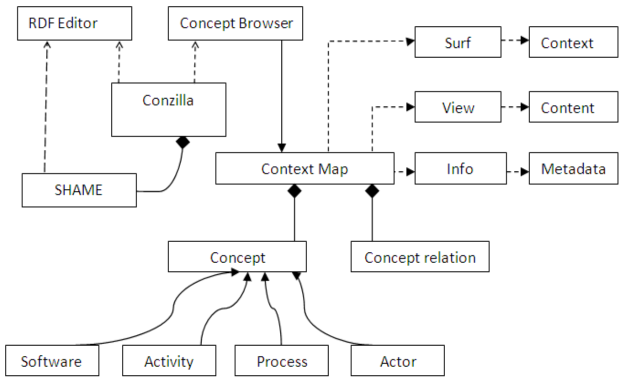

Fig. 4: Conzilla and its components

E. RDF

RDF is used as backend in Conzilla. RDF is helpful in Conzilla in following ways –

1. Context maps allow anything to be used as concepts, any relation as concept relation and any content to be described as metadata. Moreover, new concepts, concept-relations and content can be formed at any time or these may be used in different context maps. RDF supports these features as anything can be represented using URI.
2. The properties used to describe concepts, concept relations and content may be chosen from established metadata standards such as Dublin Core, IEEE/LOM or FOAF or using Formulator application of the SHAME framework, new metadata-forms can be created. Parts from established standards / schemas can also be reused leading to interoperability.
3. RDF also supports subjective metadata which is required in Conzilla as context-maps allow multiple RDF graphs to be combined to provide a subjective view of existing knowledge. In addition, by relying on a standard for knowledge expression, the information expressed by Conzilla can be reused by other applications without special knowledge of what a context-map is.

F. RDF Representation

Three layers of Conzilla interface are represented as separate triplets in RDF. RDF-expressions of the information layer are called information triples, of context-maps as the presentation triples and RDF expression of styles as style triples. Presenting context-maps in RDF allows context-maps to be extended and reused in other contexts and it also allows flexible authoring and annotation of the context maps.

Presentation triples can be stored in separate RDF graphs than the information triples as it is possible to make changes in presentation triples without changing the information triple for example, when two graphs are to be stored together or managed by tools without prior knowledge of context-maps.

Referring to Resources and Triples

The layouts of a context map refer to corresponding information triples. The layout-resource references a resource using its URI along with the reference to the container where the information triples is stored . Layout-triple refers to a reification which is a standardized and identifiable representation for a specific triple in RDF. Since a resource may be presented by several layout-resources, the layout-triple must indicate which layout-resource it refers to.

VI. Findings

As is evident from the detailed study of both these application frameworks, they focus on different aspects of semantic web. Zorica Bogdanović's model focuses on enhancing the capabilities of existing LMSes by incorporating the features of semantic web through its core logic component. It creates and uses its own ontology SEOF, that is ULM based. Education resources class of the ontology uses Dublin core metadata standards to ensure interoperability. Repository is based on this ontology and contains references to the resources that belong to LMS it is working with. This model also uses certain semantic services to integrate it well with LMSes. Moreover, it supports modular architecture making it easier to concentrate on different modules independently. On the other hand, Conzilla is purely semantic web technology. It acts as a concept browser where topic to be learnt is represented in the form of context maps which can be traversed horizontally between different maps containing same concept or vertically going in depth in one of the topics traversing concept relations. Conzilla uses RDF to store various components like concepts, concept relations and even the graphical layout. To increase reusability in Conzilla, content is stored separately from concepts and is tied to it in context maps. Layouts, styles and information about the components are also stored separately so that same concept can appear in different context maps. RForms are used to edit and create metadata and are preferred over ontology based tools to be able to incorporate all kinds of RDF data. It supports different metadata standards like Dublin core, FOAF, IEEE/LOM etc.

Although both these application frameworks utilize different aspects semantic web structure, both of them make use of visualization techniques in representing knowledge structure. First model creates visualization of the existing resources by using free visualization tool called D3 library, Conzilla depends on creation of context maps using ULM, a version of UML. It first creates context maps and then links concepts with content. Whereas main aim of Zorica Bogdanović's model is to enhance capabilities of existing LMSes bringing them into sphere of semantic web, Conzilla is a concept browser, totally utilizing semantic web technologies and incorporating and representing all kinds of resources as concepts, hence totally making space for extensibility and interoperability. Table I shows the comparison of features among these two models-

Table I: Detailed comparison between the models

Dimesion	Zorica Bogdanović's model	Conzilla
Web Technology	Extends the functionality of existing LMSes into semantic web	Completely based on Semantic web
Purpose	To improve searchability and browsability of educational resources in a LMS, using the semantics to visualize data and enrich it with information gathered from social networks and semantic databases.	To create an overview of information without losing depth by creating maps which display concepts and their relations at different level of detail. It also provides total separation of the context from its content. Also acts as RDF editor that combines graph and form-based manipulation of RDF-graphs, serves as a collaboration tool for some modeling techniques
Metadata Standards	Educational resources are annotated using Dublin Core Standards	Supports various kinds of metadata standards like Dublin Core, FOAF, IEEE/LOM
Data Repositories	Uses self designed simple ontology SEOF that contains references to LMS's database.	Uses RDF to store its components. RForms are used to edit and create metadata
Representation of Knowledge Structure	Creates Visualizations using D3 library	Creates concept maps using ULM, a version of UML
Interoperability	Framework can be used with different LMSes although LMSes are independent of each other.	Uses RDF to produce new knowledge and also to relate existing knowledge structures which is compatible with most of the semantic web enabled knowledge construction tools
Reusability	Provided through ontology used to represent data of the data that is actually stored in an LMS and cannot be used by other applications	Knowledge structures can be specified in RDF, which is compatible with most of semantic web enabled applications.

VII. Conclusion

e-learning applications changed the way learning was done in traditional classrooms by giving access to resources anytime anywhere. Learning Management Systems are being successfully used by many learners. Although they provide the facility to the learner to learner at their own pace, optimum utilization of the abundance of information lying on the web cannot be made as these resources are in control of individual organizations. Semantic web aims at increasing interoperability and reusability among different applications, so it becomes a natural choice for next generation e-learning applications which also aim at providing free access of resources to the learners across different applications. Zorica Bogdanović et al designed a framework for extending existing LMSes to semantic web through a main core logic component. Conzilla, on the other hand, is a knowledge creation tool which represents the knowledge structures in the form of context maps where all concepts, concept-maps, contents etc. are stored in RDF and can be used by any application hence increasing both reusability and interoperability. Moreover, visualization techniques used in both the frameworks help learners in understanding the concepts better. All the modules for Zorica Bogdanović's framework have not been developed yet, hence it is still a framework[20]. Conzilla is used in many applications like within an European learning network [8] as a knowledge creation tool. Although both the applications touch different aspects of the application development in semantic web, both make use of visualization tools in knowledge representation but in different ways.

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