Ontology based learner-centered smart e-learning system

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ABSTRACT. Rapid changes in learning contents and variability of the learners’ background can make e-learning systems inefficient due to their inflexibility in coping with such factors - changes and variability. In this paper, we are proposing an ontological approach in dealing with such issues. Our approach - the Ontology based Learner-centered Smart E-Learning System (OLSES) - allows instructors and learners semantically organize their learning objects to the learning contents repository and through the semantic searches, create filtered and ordered collection of learning objects as study plans - instructor-created study plans (ISP) and learner-created study plans (LSP) respectively. The OLSES continuously monitors the activities of the learners and updates their profiles accordingly so it can be used to search more suitable learning object for their learners.

In OLSES, the key to find relevant learning objects for the given topic is ontology-based semantic search. For that, all learning objects need to be registered in OLSES where an ontology-based meta-data definition is in place. In case of LSPs, learners can organize their own learning objects. This scheme builds the learner-centered learning environment by providing the learners with the relevant learning objects that suitably match with learners’ need so it help improve the learning performance at the same time.

KEYWORDS: Event analysis, Learning objects, Ontology, Smart learning management system, Study plan

Introduction

E-learning system has been serving general public in delivering knowledge for more than two decades by now. With the help from the multimedia contents and the technologies in Web 2.0, it has...
become an alternative method to traditional face-to-face learning. It can offer most of what face-to-face can offer such as multimedia lectures, question and answer, discussions, etc. Some of the issues with current learning community are how to deal with the rapid changes in the community’s learning demands and how to provide customized learning contents to the learners who have variety of educational background and knowledge levels. Course based face-to-face learning may have certain limitation in dealing with such issues but since e-learning systems are designed for individual learning and large portion of the learning is self-paced, they may be able to offer such flexible learning opportunity.

In order to provide customized learning contents to each individual learner, both learner’s profile and learning contents must be taken into account. Learner’s profile should contain learner’s educational background, performance, preference and some learning goals so they may be utilized to provide customized learning contents. Learner’s profile should follow applicable standards such as IEEE PAPI (2002) and IMS LIP (2001) so they can be interoperable among different learning management systems. Learning contents may consist of learning objects, URLs, or any other chunk of information specific to some domain. The contents must be organized in such a way where every aspect of relationships among the learning content elements must be defined. The learning objects should also follow applicable standards such as Dublin core and IEEE LOM (2002b) for interoperability. The relationships among those learning contents can be defined by using ontology language such as OWL (W3C, 2009) so the semantic search against contents repository is possible.

The smartness of the learning management system (SLMS) lies in the fact that it can promote the effectiveness of the learning by satisfying major learning needs such as providing relevant learning contents to its learners and dynamic assembly of learning contents so it can meet the needs of rapid changes in learning environment. In our view, the smartness in learning management system understands the learning needs of the learners from their searches automatically and provides learners with customized learning contents based on their knowledge level and previous performance and preferences. The smart e-Learning system in this research aims at building smart learning environment where learners’ learning contents may be adapted to new learning goals based on the learner’s performance and their learning styles as well as their
past knowledge level. In an attempt to satisfy such requirements, the Ontology based Learner-centered Smart E-Learning System (OLSES) has been proposed. The OLSES focus on a few things, namely, learner profile, semantic search and learning content management. The OLSES manages learner profile in two parts - static profile and dynamic profile - so it can support learning processes effectively. The learning contents of the OLSES are systematically organized based on the corresponding ontologies which describe the relationships among learning contents and elaborate the filtering scheme of the learning contents for semantic search against the learning contents more intelligently. The ontology also allows the system to search for appropriate learning contents semantically matched with the learners’ profile and their learning goals. Individual learner’s learning activities are continuously traced by collecting meaningful events originated by the learners including mouse click event, learning contents access log, login history, etc. The collected events are analyzed and reflected to the learner’s profile. The learner’s achievement is assessed by reviewing corresponding test results both quizzes and exam at every step of the entire study plan. The learning contents conforms IMS’s common cartridge format (IMS Common Cartridge) to promote the sharing and interoperability of the learning contents across different learning management systems.

The rest of the paper is organized as follows: Section II discusses about the related work. Section III describes smart learning with ontology. Section IV describes the OLSES. Section V concludes the paper.

### Related Works

1. **Ontologies**

Ontologies have been described as “a specification of a conceptualization”, by Gruber in 1993 (Gruber, 1993). In the real world, especially Semantic Web world, ontology is about “the exact description of things and their relationships”.

A general ontology model describes concepts of target domain, properties and attributes of these concepts, constraints on properties and attributes (Park, 2012). Additionally, it optionally examines individuals, defining a common vocabulary and encouraging a shared
understanding (Park, 2012). In this context, the ontology scheme as the conceptualization method applies to this research in that all the entities of the OLSES including learners, instructors, and learning contents can be represented and semantically organized in a certain ontology language. On the other hand, Neches et al. emphasize the importance of ontology as a method to enhance knowledge sharing and reusability across different applications (Neches et al., 1991). Once developed ontologies for a specific domain can be shared and reused for other domains by including them as the extended concepts.

As a domain modeling tool, ontology languages such as RDF (Resource Description Framework), RDFS (RDF Schema) and OWL Web Ontology Language of the Semantic Web standards describe the common vocabularies and their relationships within the OLSES (Park, 2012). As a primary representation language for domain models or ontologies, RDF allows us to define things, namely resources as well as their properties, the relationships between resources (Dey, Abowd, 2006). RDF is composed of triples (statement), subject-predicate-object, and the formation of a graph of the resources (Obitko, 2007). RDF serves as a general-purpose language for representing information in the Web; whereas, RDFS includes the vocabulary of RDF (W3C, 2004). RDFS is introduced to strengthen the semantic capability of RDF. In other words, it provides a syntactic specification mechanism to allow us to describe resources as classes and their relationships as properties (Park, 2012).

In OWL, a class denotes a group of individuals characterized by a number of common attribute(s), and it also contains a set of objects (Park, 2012). While modeling a domain of interest, inter-class relationships are described as a set of subsumption relations, a collection of superclass-subclass relationships (Spiliopoulos et al., 2009). These relationships are represented as a class hierarchy. Similarly, a hierarchy of properties, attributes, or relationships is formed to a property hierarchy in OWL scheme (W3C, 2009).

There have been many approaches on ontology-based learning, learning object designs, learning object search and reuse. Colin Knight et al. (2006) proposed a framework for bridging learning design and learning contents. They used ontological approach for reusing learning objects. Ontologies for personalized e-learning framework were proposed by Nicola Henze et al. (2004). They
showed how ontologies can be used for building adaptive educational hypermedia systems. For reusing learning object content, Dragan et al. (2005) proposed a method using two ontologies - content structure ontologies and domain ontologies - to improve the search for learning objects. Another attempt to improve the semantic search is done by Rim Fiaz et al. (2012). Their approach was to use semantic annotation automatically to improve the correctness and search time. Mario Arrigoni et al. (2009) utilized ontology to search learning objects from the repository and capture specific domain knowledge. However, most of the works focused on learning contents and search mechanism. They are lacking in combining learner’s background with the kind of learning objects. In order to improve learning performance, learner’s learning needs must be satisfied, the level of learning objects must match with that of learner’s, continuously monitor learner’s activity, etc. are needed to improve overall learning performance. In our proposed system - OLSES - we focus more on the learners so they learning performance may be improved.

2. Applicable industry standards

Learner profile

There are two competing standards in industry – IMS LIP and IEEE PAPI. In our approach, we mainly followed IMS LIP and its XML schema format to represent the basic learner profile and study plan completion information. In IMS Learner Information Profile, there are 11 core structures to describe a learner such as identifications, security keys, transcripts, goals, qcl (qualifications, certifications and license), activities, interest, competency, relationship, affiliation and accessibility.

Learner profiles may be customized depending on the application area as suggested by Y.T. Song et al. (2013). The main purpose of conforming to industry standard such as IEEE PAPI and IMS LIP for the learner profile is to make our system interoperable with the other systems. IMS LIP specification also defines a set of packages in XML that can be used to import data into and extract data from IMS compliant learning management systems.
Learning Object
Learning object may be termed as reusable learning resource that has meaningful chunk of information in some domain. It should be specified in such a way that can be easily searchable for broader use. In our proposed approach, we have followed one of the industry metadata standards - Dublin Core (2002) and IEEE LOM (2002b) - to express each learning object element effectively searchable and interoperable in the networked environment. We have used the following elements to express the contents: title, description, keyword subject, creator, type, audience, publisher, identifier, format, size, typical learning time, difficulty level, language and cost. One added element is “cost” that we used to describe the price value associated with the learning object.

Smart learning with ontology
A collection of learning objects that is relevant to learner’s specific needs may be assembled dynamically to provide learners with the most relevant learning materials suitable to their level. The collection is termed a study plan that is dynamically adapted to support the best of their needs. In response to such needs, the OLSES system employs a set of new approaches - ontology based learning content management, semantic search on relevant learning objects, learner performance management through learning event analysis and learning history.

1. Ontology-based learning object organization
The ontology has been picked up by the OLSES as the underlying scheme which organizes the learning contents because the ontology is essential to semantically organizing learning contents and enhances the interoperability and reusability of learning contents across a variety of domains and heterogeneous learning management systems. The learning content repository of learning management systems contains a set of learning objects. Each learning object represents a piece of information that is meaningful to a certain domain or topic. Furthermore, as a specific learning object of a domain is related to any different domains or topics, it can be reused in a variety of study plans. As a solution, the ontology-based semantic graph of RDF triples is formed by defining various relationships among
learning objects in various domains. For that reason, it is important to keep the size of learning objects the smallest meaningful possible for the broader use in any related domains. Entities in the OLSES are conceptually specified as objects using Protégé Ontology Editor (Noy, Tu, 2003) and Knowledge Acquisition System. RDF is a primary representation language for domain models or ontologies (Park, 2012).

Each learning object must be registered before it is available to the learners. During the registration, each learning object establishes its relationships with other learning objects in various ways such as dependency, relevancy, difficulty level, etc. so when a semantic search is performed by a learner, all the learning objects that are related to search keyword(s) may be retrieved and presented to the learners.

Filtering and sequencing resulting learning objects can help the OLSES prepare a study plan that is relevant to the learners who may have different background and performance. The search process is performed through SPARQL (McCarthy, 2005), a query language and data access protocol for the Semantic Web (Dodds, 2005), worked for RDF graphs located in triple store. The study plan building process is described in the following section in more detail.

2. Study plan building with semantic search

A study plan is a collection of learning objects that learner can use to study a specific topic. The OLSES accommodates various multimedia formats such as pdf, text, audio, etc. but default format is common cartridge (Dublin Core Metadata Initiative, 2002). The system allows both learners and instructors to create their own study plan in the form of Learner-created Study Plan (LSP) and Instructor-created Study Plan (ISP). Learners can retrieve and choose ISPs. When a learner completes an ISP, it is recorded in the learner’s static profile.
In order to search for the relevant learning objects from the repository, a learner or an instructor queries the system with ontology-based semantic search and then customizes the returned search results, usually a set of the most related learning objects that varies depending on learner’s background described in the learner’s profile. The factors affecting the search generally include learner’s educational background, learning style, learning history, etc. Once the result is presented to the learner, (s)he needs to filter out the irrelevant learning object(s) and streamline the set of learning objects to get the properly sequenced study plan for their purpose. ISPs are accompanied by test sets which correspond to quizzes and exams. When a learner selects an ISP, the learner has to finish all the learning objects and quizzes in the ISP. To complete the ISP, the learner must pass the final exam supplied by the ISP. If the learner gets satisfactory score in final exam, the study plan is completed. Whereas, LSPs are not required to have test sets. In the OLSES, all ISPs are assigned a plan code for the purposes of system-wide identification so learners can locate the ISP and use it. In case of LSP, it is regarded as a self-study material available to the learner only.

The semantic search is a process that leverages the power of the RDF graph technology we are using to store metadata about the learning objects. For that purpose, SPARQL queries may be used to produce semantically meaningful results. With SPARQL queries, we can make use of the properties of the graph and combine
that with the knowledge about a learner's background for more powerful search results. From the search results, learners can pick and choose only the relevant learning objects they would like to use in their own study plans. The selected learning objects may be sequenced according to the dependencies that may exist among the learning objects.

3. Dynamic learner performance management

The dynamic profile is created automatically whenever a learner registers to the OLSES. It keeps track of the learner’s scheduled study plan(s). It also shows that status of a study plan - in progress or completed. In addition to the learning achievements evaluated by the tests, learning pattern or styles can be collected by the software agent. During the study process, the OSLES monitors learner's study patterns by collecting events such as login, study plan selection, learning object selection, log out, etc. Each captured event is stored in the event log for further analysis. The analysis results are stored in the learner's profile so they can be used for future learning object search.

4. Learner-centered learning

Vast majority of our curriculum in any educational institutes consist of lecture and textbook. Even though that set up has been used in education community for the last several thousand years, it comes short in meeting the needs of individual learners. As Donald A. Norman and James C. Spohrer (Norman, Spohrer, 1996) pointed out, there are three dimensions of instruction - engagement, effectiveness, and viability. In OLSES, learners are allowed to create their own study plans and follow them at self-paced. Since the topics are from the learners, they are engaged in the topic more rigorously. The OLSES monitors their learning activities and guide them to complete their own study plans. The contents of the OLSES come from instructors, WWW, and even learners themselves to meet the needs of learners' learning needs. Through the filtering and sequencing of the semantic search results, learners effectively build the learning contents of each study plan that satisfies their learning needs.
The learner-centered smart e-learning system (OLSES)

The Learner-centered Smart E-Learning System (OLSES) consists of the subsystems including the learner profile management system (LPMS), the learning contents management system (LCMS), the event management system (EMS), the study plan management system (SPMS). This section first explains the ontology specification of the OLSES with the description of its application environment of RDF graph and SPARQL query.

1. Ontology for the OLSES

The ontology enables the learning system to be capable of representing any and explicitly visible information as well as invisible factors during learning process. In addition to tangible results like exam grades, learners’ dynamic profiles should include frequently changing knowledge background, achievements, and preferences which are naturally uncertain information depending on the Learner’s Model. In order to model the incomplete and imprecise information, ontology-based modeling is applied to the OLSES as the representation scheme.

1.1 RDF graph

The RDF graph of the OLSES describes learning objects by defining the class hierarchy and properties in the form of triple statements using Protégé Ontology Editor. In addition, Virtuoso Universal Server is used to provide transparent universal access to heterogeneous data sources including Web, files, and conventional database servers by exposing all of its functionality to Web Services. Within the OLSES environment, the completed RDF graph, one of Native Virtuoso XML Data like Style Sheets, XHTML, XSchema, etc., is managed via the data access service of Virtuoso Database Engine. Virtuoso is extended to support SPARQL, the standard query language for RDF and the Semantic Web. The OLSES is implemented by using .NET framework, C#, and dotNetRDF. They are designed for reading and manipulating RDF files. The framework enables the system to incrementally add RDF graph elements related to smart learning and extended concepts.
1.2 Ontology classes
The ontology of the system includes Learning Object, Study Plan with ISP and LSP, User with Author, Instructor, Learner, and Administrator, Test with Exam and Quiz, Certificate, and additional classes to supplement learning object which are contained within “Learning Object v1 Metadata Final Draft” provided by Learning Technology Standards Committee of IEEE (2002b). In this research, only the meaningful six elements out of nine sub categories are chosen and associated with the Learning Object.

1.3 Ontology relationships
The classes used in the ontology are related each other with various relationships. Those relationships are defined in the object properties section as shown in the figure 1. For example, “isSuperConceptOf” is a relation between learning objects, “isPassedBy” is a relation between a test and a learner, etc.

2. The OLSES system components

2.1 The learner profile management system (LPMS)
LPMS manages learners’ static and dynamic profiles. The static profile contains the learner’s basic identification information and academic achievement data - completed study plans (ISPs). This information can be used to provide better search results in future semantic searches. The dynamic profile keeps track of the learner’s study schedules and their progress by monitoring each study plan’s completion status.
2.2 Learning content management system (LCMS)

Network Overview of Learning Content Management System

Figure 2. Class hierarchy and object properties of the ontology used in the OLSES

Figure 3. LCMS overview
LCMS is a storage management technique where learning objects are stored in an efficient way for the smart retrieval. Even though learning contents can be in any format, Common Cartridge is used as default format so various types of learning contents can be packaged together for easy access. LCMS has two main parts - learning object repository and their metadata storage. We have utilized globally unique identifier (GUID) for each learning object in the repository and Openlink’s Virtuoso server for metadata storage. Each metadata for a learning object has RDF triple format so the collection of the triples - triple store - can create a graph that is used to do semantic searches using SPARQL queries. To enable SPARQL queries, two classes of the APIs - TripleModel and QueryModel from dotnetRDF\(^3\) and Virtuoso universal server are utilized.

Learning Object Registration is the process for populating the RDF graph stored in the Virtuoso with metadata about the learning objects. Once the objects are registered, that can be searched semantically for more relevant results to the learners. Ontology language such as OWL is used to define how learning objects are related. Learning Object Repository is the physical repository where the actual learning objects are stored. Since the study plans (ISPs and LSPs) contain only the links to the actual learning objects, it allows broader use or reuse of the stored learning objects in various study plans.

All learning objects must be registered before it is available for the search. When registered, the TripleModel is used to create metadata for registering learning object as triples. Currently only keywords are used to search related learning objects. The QueryModel is used to communicate with Virtuoso server. The QueryModel creates parameterized query and send that to the Virtuoso server. The structure of the QueryModel is shown in the Figure 3. The results of the query are used to create study plans.

2.3 Event management system (EMS)

Learner’s activities during learning process are monitored for analyzing learner’s learning patterns, performance, etc. The EMS is capturing the events through event listener. The captured events are stored in the log file for future analysis. Event analysis is done by software agent that monitors learner’s activity, collects corresponding events, and stores those into event log for the
analysis. The collected events are used to identify duration of study for each learning object, number of times certain study plans or learning objects selected, and total time for using the OLSES. The list of captured events is shown in the Figure 4.

2.4 Study plan management system (SPMS)
Study plans may be created by both learners and instructors. Instructor created study plans (ISPs) are created for the learner’s to study specific topics. They can be searched by the learners. When completed by the learner, the result will be recorded in the learner’s static profile. The study plan creation process is illustrated in the figure 5.
LSPs are for the learners to organize their own study plans. Once a LSP is fully studied, it may be checked off by the learner, remove it from the current study plans and stored as a previous study plan.

The proposed ISP has the following structure:

$$\sum_{i=1}^{n} \{\text{learning object}(i) + \text{quiz}(i)\} + \text{exam}$$

where $n$ is the number of learning objects in the ISP. Each learning object simply has the link to the learning object in the repository for the broader use. DSP has similar structure but no quizzes and an exam.

The OLSES is following Dublin Core and IEEE LOM for its metadata for learning objects. The figure 6 is showing the process of creating study plans. The learning objects in the search result may be
selected to be a part of a study plan. Selected learning objects may be sequenced depending on the needs of a learner or an instructor. After the filtering and sequencing, the finished list of learning objects may be saved to the database for later use. In case of ISP, it will be available for the learners to use and for LSPs, it is only for one particular learner.

**Conclusion**

In this paper, we have proposed a new way of delivering knowledge to the learners in their preferred way – learner-centered learning. The purpose of the learner-centered learning is to help learners focused on the learning process more intensively so they can achieve their learning goals. For that it is necessary to understand the learner’s learning environment such as understanding learner’s learning pattern, available time to study, and knowledge level on their topic of interest. By considering these factors, individualized learning contents may be delivered to the learners. In our approach, we have Organized learning objects with ontology so semantic search is possible – the metadata for the learning objects is saved in triple format.
Figure 5. OLSES system flow overview
Learner profile has two types – static and dynamic – one for managing learner’s personal info, performance, preference, and learning goals and the other for managing their study plans both ISPs and LSPs and monitoring the progress. Study plans have two types – instructor created study plan (ISP) and learner created study plan (LSP) – for greater flexibility and learner’s engagement. Through event analysis the OLSES monitored learner’s learning patterns – captures learner’s learning related for the analysis to provide more individualized support for the learners. Figure 6 shows study plan creation process.

As for the proof of our concept, we have implemented what we have proposed in the paper. RDF (resource description framework) triples are used to describe learning objects and stored in the Virtuoso server so SPARQL query against the triples is possible. GUID (globally unique identifier) is used to store various resources related to learning object in one place. Our system supports Common Cartridge format for contents packaging and interoperability.
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References


Makis Leontidis, Costantin Halatsis (2009), Supporting Learner’s Needs with an Ontology-Based Bayesian Network, The Ninth IEEE International Conference on Advanced Learning Technologies (ICALT), Riga, Latvia, July


OpenLink Software, OpenLink Virtuoso Universal Server: Documentation http://docs.openlinksw.com/virtuoso/


Rim Faiz, Boutheina Smine, Jean-Pierre Desclés (2012), Relevant Learning Objects Extraction Based on Semantic Annotation of Documents. WIMS ‘12: Proceedings of the 2nd International Conference on Web Intelligence, Mining and Semantics, June


Song Yeong Tae, Glassmire Kriss, Afsana Atiya, Yoon Yongik (2013), Converged Learner Profile in MOOC Environment. Proceedings of the 5th ICMIA, Jeju, Korea, June

W3C Recommendation (2009), OWL 2 Web Ontology Language Primer, http://www.w3.org/TR/owl2-primer/

W3C School, Introduction to OWL, http://www.w3schools.com/rdf/rdf_owl.asp

Sintesi

La necessità di aggiornamento continuo dei contenuti e la variabilità dei background degli studenti richiedono ai sistemi e-learning una flessibilità spesso di difficile realizzazione, dal punto di vista tecnico, e ideazione, sul piano teorico. L’approccio ontologico del sistema OLSES (Ontology based Learner-centered Smart E-Learning System) permette a studenti e docenti di organizzare e ricercare i learning object più appropriati al raggiungimento di determinati obiettivi formativi, attraverso una ricerca strutturata mediante l’uso delle ontologie di metadati e criteri di tipo semantico (ontology based semantic search). Inoltre, il sistema è in grado di aggiornare i piani di studio così predisposti attraverso il monitoraggio continuo delle attività dello studente, aggiornandone il profilo e, conseguentemente, il repository di learning object associato ad esso.