An Ontology-based Architecture for Context Recommendation System in E-learning and Mobile-learning Applications

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***Abstract*—Distant learning is an alternative way of education that offers a remote learning experience without being in a traditional classroom. With the emergence of mobile devices, distant learning is passing from electronic learning (e-learning) to mobile learning (m-learning) which makes learning even more widely available. This availability has put emphasis on the need of having platforms that are delivering learning contents corresponding to learner's learning environment. With the huge amount of learning materials available on the internet, it's become difficult to find the suitable ones. Although, recommendation systems can be the solution for this problem. However, these systems are still less used in e-learning and m-learning in comparison with other fields (e-commerce, social media...). Hence, to make these systems more relevant and performant, in this paper we propose to take benefits from semantic web technologies by proposing to add a semantic layer in 3-tiers classical web application's architecture. This layer will hold three ontologies: The Learning Context Ontology is a domain knowledge for gathering the learning context information (Profile, Social interactions, learning activities, and device specifications), The Learning Content Ontology is the Learning Object Ontology, and the Learning Design Ontology is the ontology to hold the sequenced learning activities. The OWL Rules filtering will be used as a recommendation technique.**

***Index Terms*— Semantic Web, E-learning, M-learning, Learning Design, OWL Ontology, Recommendation system, Context-aware, SWRL.**

I. Introduction

Nowadays, e-learning platforms extended in m-learning ones are widely used for education for both universities and companies. Because the learners are given the opportunity to access electronic learning courses through the network. This access allows developing learners skills, while making the process of learning independent of time and place. However, the continuous development of e-learning and m-learning platforms has led to a huge amount of learning materials available on the network. It is time-consuming for learners to find the learning materials that they really need. "The one size fits all" is no more working. The challenge is to deliver to the learners the right learning materials at the right time.

To lead a successful learning experience, the learning materials should be recommended to the learners in coherence with their learning context. The contextual information such as; prior knowledge, activity history, interests, social interactions and device specifications; should be taken into account in order to deliver to learners the learning materials suitable to what they really want [6, 15]. This new learning paradigm is called context-aware e-learning [7] and m-learning [8].

The development of context-aware applications should be supported by adequate context modelling and reasoning techniques. As context can be considered as a specific kind of knowledge, it can be modelled as an ontology. Ontology-based models of context allow representing complex context knowledge and providing a formal semantics to context knowledge, which supports the sharing and/or integration of context information [8]. Most of current e-learning and m-learning platforms are based on a layered architecture which encapsulates the three levels of abstraction: data, application and presentation. In this paper we propose a re-engineering of this architecture to integrate a semantic layer that holds an ontology and rule based approach for semantic recommendation. We aim to use the ontology as a domain knowledge for gathering the learning context information and OWL Rules filtering will be used as recommendation technique.

The remainder of the paper is structured as follows. Section 2 summarizes the state of the art on semantic recommendation systems. Section 3 describes the proposed semantic architecture for context-aware applications. Finally, Section 4 concludes the work.

II. Related Works

There have been many researches about personalized learning using semantic web technologies, mainly ontologies [9, 13]. Several ontology-based approaches for context-aware e-learning platforms were proposed. Authors of [10] propose to make recommendation to realize context-awareness in learning content provisioning by exploiting knowledge about the learner (user context), knowledge about the content, and knowledge about the learning domain. For this purpose they designed three ontologies with a focus in learner's prior knowledge and his learning goal in the recommendation process. But the social learner interactions are not taken into consideration.

The work presented in [11] proposes to recommend learning content based on the expert learning object knowledge base and personal learning progress where sequencing rules

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were used to connect learning objects. The rules were created from the knowledge base and competency gap. However, all the focus is in the learning content; the authors do not study the learner profile and its social interactions that are important contextual information.

[12] Proposed a framework to observe personalization in e-learning system based on ontology. They created user ontology, domain ontology and observation ontology. They also used reasoning mechanism over distributed Resource Description Framework (RDF) annotation. The query rule language used in this system is Triple. However, OWL has more powerful expressive capability than RDF.

[13] proposed a semantic recommender system for e-learning. The proposed web based recommendation system comprises ontology and web ontology language (OWL) rules. It consists of two subsystems; Semantic Based System and Rule Based System. Modules for either subsystem are; Observer, Learner profile, Recommendation storage and User interface. In this work, authors do not explain how they built the ontology and wich Rule language they work with.

Coming to m-learning, several approaches have been presented to take in consideration the mobility feature of the device. [8] Proposed a context ontology network to model context-related knowledge that allows adapting applications based on user context. [15] Presented an adaptive system based on the semantic modeling of the learning content and the learning context. The behavioral part of this approach is made up of rules and metaheuristics to optimize the combination of pieces of learning content according to learner's context. [16] Proposed an approach for context integration and aggregation using an upper ontology space and a unified reasoning mechanism to adapt the learning sequence and the learning content based on the learner's activity, background, used technology, and surrounding environment.

Our work differs from these researches by proposing a re-engineering of the layered architecture of current e-learning and m-learning platforms by integrating a semantic layer that will hold the semantic recommender system. Our proposed semantic recommender consists of two subsystems that are: LMS (Learning Management System) Ontology Subsystem and the Semantic Rules Subsystem.

III. Semantic Web Architecture

Most of the current e-learning platforms are based on a layered architecture which encapsulates the three levels of abstraction: data, application and presentation. The first layer is concerned with the storage of the data. The second handles the requests of the user interface by querying the storage media, after performing the various treatments and returning the results to the third layer this last layer then manages their display. These solutions are not sufficiently aware of the learner context. The context-awareness is highly recommended to deliver to the learner the learning material relevant to the current situation of the learner. To achieve this, we adopt the ontological approach to define a model to represent and manage context information. In this work, we want to perform a re-engineering of this architecture, with a view to incorporate the technology of the Semantic Web. To this end, we are proposing to insert a Semantic Layer between the layer of data and that of the application. Figure 1 resumed schematically this architecture.

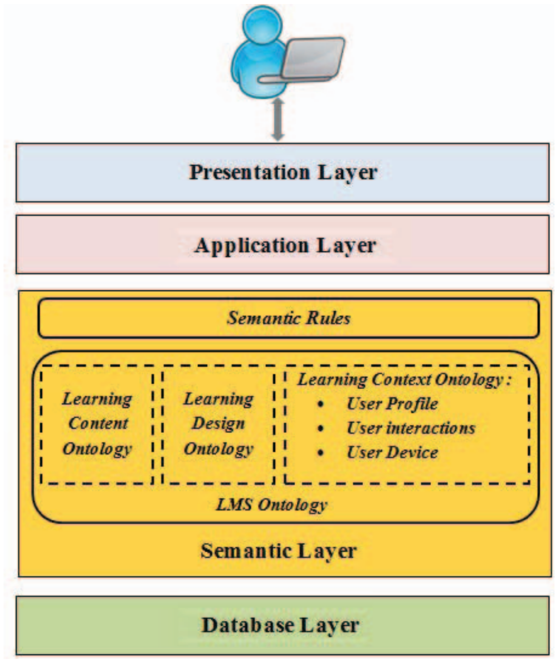

Fig.1. Semantic web architecture

In the following, we focus on the semantic layer of our proposed architecture. It's organized in two main parts:

- LMS ontology
- Semantic rules

A. LMS Ontology:

Our approach considerably relies on semantic modeling of the learner's context and environment. For this purpose, we make use of ontologies and Semantic Web technologies. The LMS ontology is the ontology of the whole Learning Management System. Since we are working on current e-learning and m-learning platforms that are already running and designed with UML diagrams and in order to limit the amount of effort required to build such a consistent ontology, we propose to build this ontology by adopting the approach UML-To-OWL proposed in our previous work [1]. Then the resulted OWL ontology will have some changes to be able to model the learner context. In order to keep the modeling task manageable, we divide this ontology into three sub-ontologies that are: Learning Content Ontology, Learning Context Ontology and Learning Design Ontology.

a) Learning Content Ontology:

A learning content is an instantiation of Learning Objects-abbreviated LO. The LO are a digital small size components of a learning course which can be reused several times in different learning contexts. However, these Learning Objects are often designed and developed by different organizations and authors which make the learning content semantically heterogeneous.

This heterogeneity affects its reusability. So it is essential to think of a shared modeling of LO in order to make them easily accessible, usable, reusable and semantically interoperable**.**
Different standards have been defined to help the development of learning systems and the representation of their joined LOs. Making use of these standards, not only guarantees the interoperability but also the quality of the system [3]. Among these standards, we can cite LOM, SCORM and the IMS-LD. LOM is interested in learning content description, SCORM in content structure, and the IMS-LD in learning scenario. In our work, we are interested in LOM standard. LOM (Learning Object Metadata) is a standard developed by IEEE consortium. It defines the structure of an instance of metadata for a LO. It is composed of a set of 80 elements divided in 9 categories performing each a different function [2]: General, Lifecycle, Meta-Metadata, Technical, Educational, Rights, Relation, Annotation, and Classification.

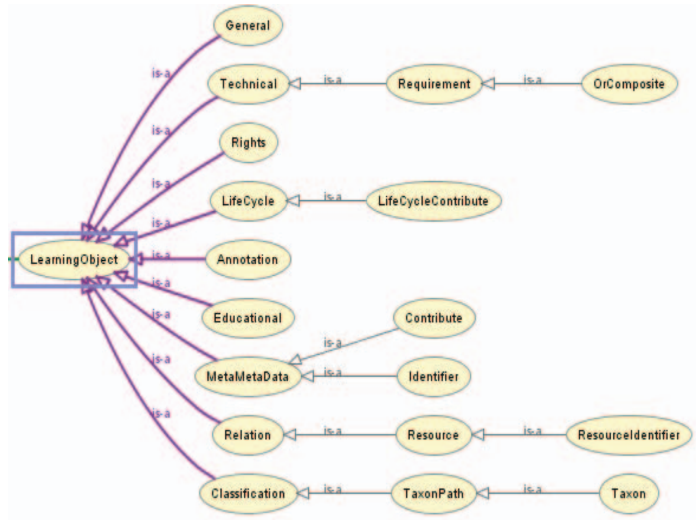

Fig.3. Learning Content Ontology designed with Protégé according to LOM Standard

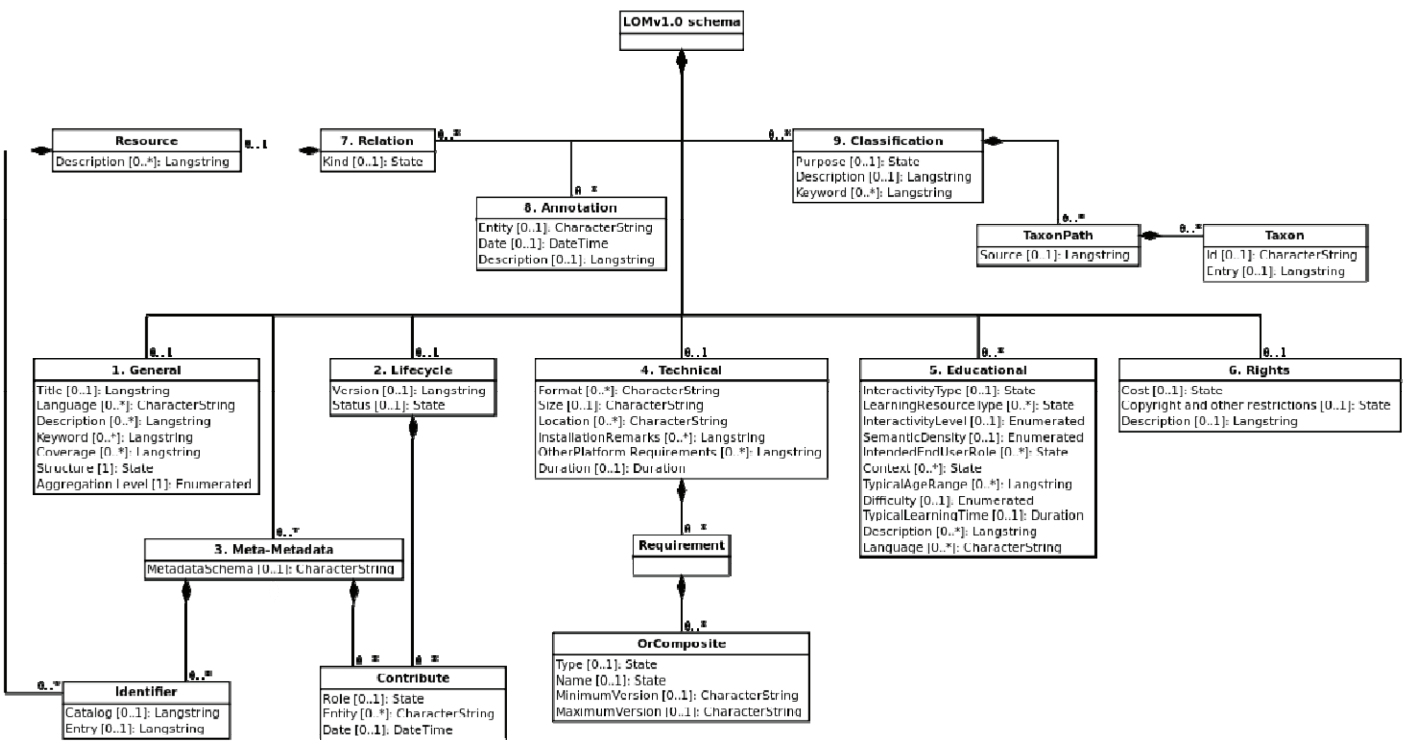

Fig.2. An UML diagram of IEEE1484.12.1 Learning Object Metadata (LOM) base schema.

To capture the semantics of LOs, we present this standard in ontological way. We get the LOM ontology by converting the UML diagram of IEEE1484.12.1 Learning Object Metadata (LOM) base schema to OWL ontology. The conversion process adopted is the one presented in [1]. Figure 3 shows the built ontology using Protégé.

Every learning Object is described by 9 categories of information; General, LifeCycle, Meta-Metadata, Technical, Educational, Rights, Relation, Annotation, and Classification .These information are presented in UML as composition relationship. To model them in OWL ontology, we used our conversion process in which we proposed to model every composition using the Collection Ontology described in [1].

b) Learning Context Ontology:

The context of learning is a crucial aspect in e-learning and m-learning. Therefore, it is important to determine according to the learner current context what are the relevant learning materials to deliver, how, and at what time. All the learning process must be adapted to context changes. To take into account the context in an e-learning and m-learning system, it is necessary to find a way to represent it. This representation must provide a coherent model to store and process the context information in order to respond to the environment changes. At the semantic level, we define context information using a Learning Context Ontology that includes three interrelated sub-ontologies: Learner-Social ontology, Learner Activity ontology and Device ontology. This ontology will represent and store every learning context's information.

Figure 4 shows the Learner Profile-Social Ontology that is built from FOAF ontology. [5] defined FOAF Ontology as "a popular ontology for the representation of personal profile information and social relationships among groups of peers. Built on the Resource Description Framework (RDF2) Semantic Web language, FOAF gives a representation of a social relationship network as a graph structure, where people connected to each other by a given relationship are represented as graph nodes connected by edges. Personal profile information is also represented by RDF subgraphs connected to people nodes". This ontology is widely used, [4] claims that the class foaf:Person has nearly one million instances spread over about 45,000 web documents. So it's relevant to reuse it to represent the context information about the learner profile and its social interactions.

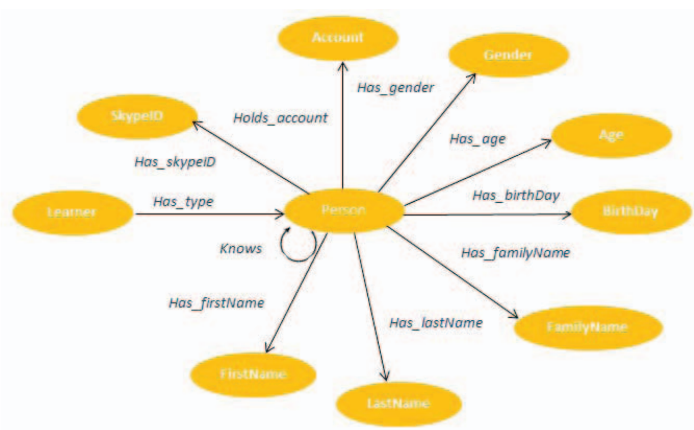

Fig.4. Learner-Social Ontology

Figure 5 shows the Learner Activity Ontology. This ontology represents and stores the different information about the learner's pedagogical interest and behavior. It shows in which topic the learner is interested, in which courses is enrolled and what are the specific activities he did.

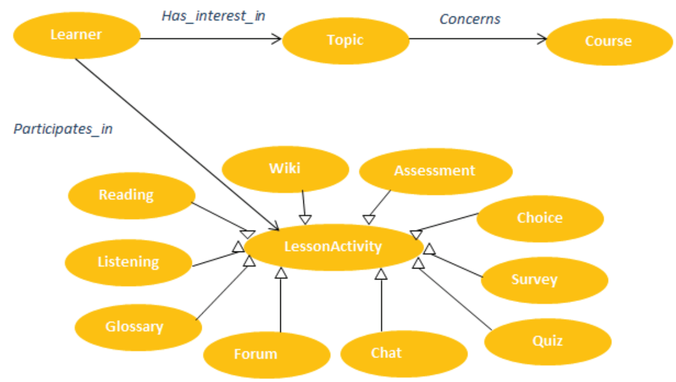

Fig.5. Learner Activity Ontology

Retrieving the context information is not complete without taking in consideration the device type. It determines whether we talk about an e-learning experience or a m-learning one. The device mobility plays an important role to decide which learning experience will be delivered to the learner. Having a mobile device that has specific location and battery life will determine which the most suitable learning content to have. For example if we are connected from a metro or public transportation, it will be suitable to have a learning content with a short duration because of the short time we spend in those places. The battery life of the device also should be taken in consideration, because the delivered learning materials should be in coherence with it. We can't have a long video course with a low battery life. Figure 6 shows the Device ontology that represents and holds the device specific information.

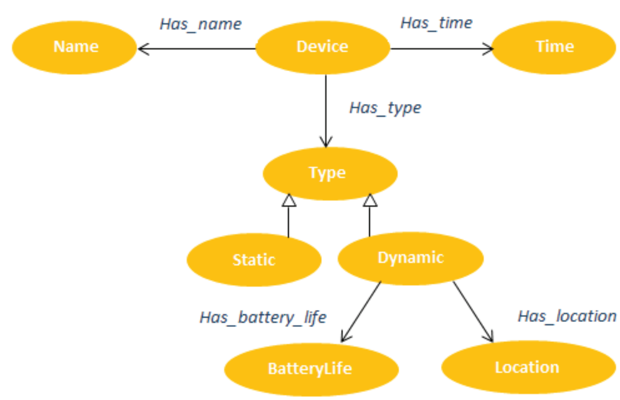

Fig.6. Device Ontology

c) Learning Design Ontology

Learning designs have the potential to repurpose learning content. They can choreograph the order in which the content will be presented, how it will be integrated in learning support services, how it will be sequenced and how it will be assigned to learners in a lesson [14]. The learning design is built with sequenced learning activities that hold the suitable learning objects.

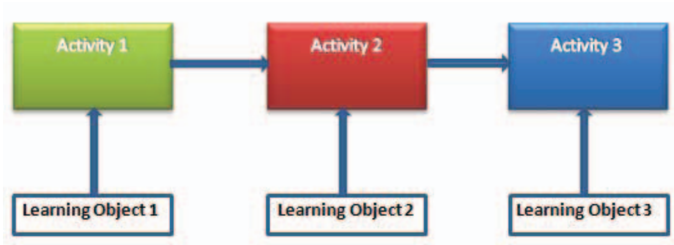

Fig.7. Example of a Learning Design

Figure 8 summarizes the whole LMS Ontology and the interconnected sub-ontologies described previously.

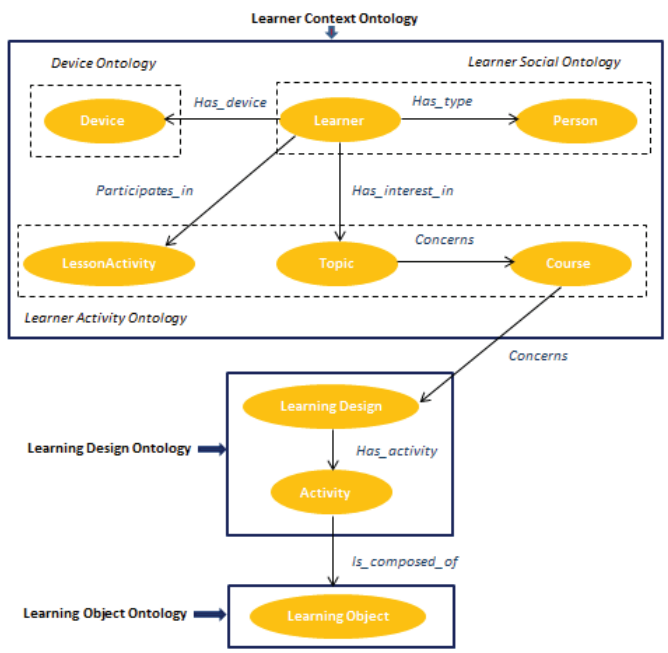

Fig.8. The LMS Ontology

B. Semantic Rules

To take into account the context in an e-learning and m-learning system, it is necessary to find a way to represent the context in the latter. This representation should provide a coherent model to store and process the context information in order to react to the environment changes. The e-learning ontology is the context model. After building this ontology, it's time now to apply techniques of refinement and adaptation of the LOs on it to deliver to the learner the learning object relevant to its context. A method to filter the LOs is to apply a set of business rules, indicating what LO to use in what context. These filtering rules will be used as our recommendation technique. They synthesize the domain knowledge and business constraints that must be met by the system. Business rules are translated into SWRL (Semantic Web Rule Language).

SWRL (Semantic Web Rule Language) is a language for Semantic Web rules, combining the OWL - DL and OWL-Lite with the unary/binary sub-language of RuleML (Rule Markup Language). The structure of SWRL rules consists of an antecedent and a consequent. A rule means ≪ if the antecedent conditions are maintained, then the consequent conditions must also be applied.

If Antecedent Then Consequent
Antecedent (Body) → Consequent (Head)

Example of a SWRL Rule:

If a Learner x knows (FOAF Object Property) another Learner y who is interested in a Topic T, then the learner x may also be interested in the same Topic T. So in this case, it's relevant to recommend to the Learner x the topic T. This recommendation rule is expressed with SWRL language as:

Learner (?x) ∧ Knows (?x, ?y) ∧ has_interest_in_topic(?y, ?T) → has_interest_in_topic(?x, ?T)

IV. Conclusion

Context-aware applications play an important role for education, especially in e-learning and m-learning. Context recommendation systems give the opportunity to learners to lead a successful learning experience by getting the right learning materials that suit their needs in the right time. Semantic web technologies make these systems more performant and relevant. In this paper we have proposed our semantic web architecture for current e-learning and m-learning platforms. This ontology and rule based architecture is proposed to make use of ontology as a domain knowledge for gathering the learning context information and OWL Rules filtering as a recommendation technique.

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