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Ontology-Driven and Semantic Web-Enabled Framework for Intelligent eLearning System

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ABSTRACT

Due to the rapid advancements in technology in different fields, the Internet has become an essential tool in our daily lives. In particular, the internet and eLearning technologies are bringing about a radical change in education. In this paper, a semantic-based framework architecture for intelligent eLearning system is proposed. Requirements, concepts, and technologies needed to build such an intelligent system are examined. The services offered by the proposed eLearning framework that serve both learners and tutors are presented. The main emphasis is the semantic-based search process. The approach is based on metadata to suggest related course material to the learner. In addition to the semantic search, proposed services include a question answering system, a recommender system, and a content annotation.

Key words: Learning content management system (LCMS), metadata, ontology, semantic search, semantic web, web intelligence

1. INTRODUCTION

The popularity of the Internet is increasing most rapidly and the use of the Internet as a tool and platform for research and development has gained increasing importance. In particular, the Internet is used to develop innovative approaches in the education sector to achieve its goals. Considerable efforts are still being made to introduce eLearning technologies in schools and higher education worldwide. Simply stated, eLearning makes use of electronic means of communication, training, and education to improve the teaching and learning process. According to The American Society for Training and Development (ASTD) [1], electronic-learning (eLearning) is essentially learning that is supported and facilitated and via information and communications technology (ICT) using a broad set of applications, and processes which comprise courseware learning and digital educational technology, which is conveyed via the Internet, satellite broadcast, interactive TV, audio- and videotape, and intranets. eLearning also means online learning, online educational platform/portal, computer-based learning, web-based learning, virtual learning environment, virtual classrooms. It can be self-monitored or tutor-guided and includes media in the form of text, image, audio, animation, and streaming video [1], [2], [3].

eLearning can be divided into two types, Simultaneous eLearning, and Asynchronous eLearning. Simultaneous eLearning requires that both the learners and the tutors be connected to the Internet and use the eLearning systems at the same time. Examples of tools include whiteboard, virtual classes, video- or audio-conferences, chat rooms [4], [5]. Its main advantage is that the learner can get immediate feedback from the tutor just like in a traditional classroom but at a distance. Asynchronous eLearning, however, does not require simultaneous presence of the learner and the tutor. The learner can use the eLearning system at his/her appropriate time, pace and required efforts, and is therefore able to re-use the material and refer to it electronically as needed. Nevertheless, there is no direct interaction between the tutor and the learner, which can constitute a handicap for some learners. Examples of tools include e-mails, websites, and forums [5], [6].

eLearning is becoming more and more popular and new forms of eLearning systems are being investigated. eLearning solutions are moving from being plain web-based information repository to educative learner-centric environment. Current research studies claim that conceptual framework as well as theoretical and experimental research are needed to develop more effective eLearning systems [7], [8], [9].

The development of eLearning systems that concentrate on the learner and knowledge on human learning process is becoming

increasingly important [10], [11]. An accurate and deep understanding of learning performance is crucial to the development of eLearning systems with high capacities for personalization [12], [13].

Research and development on eLearning and ICT-based education has led to the use of efficient web-based platform where tutors and learners communicate and exchange teaching material in real-time and in a cost-effective way, in addition to archiving the digital teaching material in the form of eContents [14]. The semantic web is playing a major role in such systems. The semantic web is an enhancement to the existing world wide web that aims at associating meaning with the information on the web and providing more intelligent technologies that can provide comprehensible services to the web users, including both humans and machines. Ontology is a vital component of the semantic web. Ontologies can be defined as the description of a set of concepts, including their properties and the relation between them, in a given domain. Such technologies are increasingly influencing development of eLearning systems and their related applications.

It is argued that the semantic web will rely on ontology-based technologies and intelligent agents in processing semantic information. Nevertheless, the challenge is for semantic services to deal with different ontologies and schemas when dealing with the semantic integration problem.

Another essential requirement is metadata interoperability which is the capability of exchanging and understanding descriptive data of objects in the system. There seems to be no unified and standardized metadata terminology so far. Ontologies can be used instead of relying on using unified metadata.

In this paper, we propose an architecture framework to develop intelligent eLearning systems based on the semantic web and ontologies.

The rest of this paper is organized as follows. Section 2 gives an overview of the concepts and technologies used in this paper as well as eLearning requirements. We review some related work in Section 3. The proposed framework is presented in Section 4. Section 5 illustrates the semantic search approach. Conclusion and future work are given in Section 6.

2. CONCEPTS, TECHNOLOGIES AND REQUIREMENTS

2.1 Why eLearning?

The Internet and the World Wide Web have a huge impact on the daily life of learners and tutors. In particular, eLearning systems are increasingly used as they can increase productivity and efficiency in education. Users of eLearning systems can access learning resources at any time from any place. In addition, eLearning can meet diverse user's needs and requirements to maximize information retention. For instance, learning content can be customized to meet specific user's need. The content can be made accessible to many participants with various backgrounds and levels of instruction and each participant can gain the appropriate and suitable amount of knowledge. eLearning is suitable in distance learning, but it is also used in combination with face-to-face learning which is called blended learning.

2.2 Why Learning Content Management System?

One type of eLearning system in common use is the Learning Management System (LMS) which is a software application that provides an environment for producing, storing, tracking, retrieving, and delivering educational and training courses and programs. The first LMS was developed and used in the higher education sector, but such systems are now deployed in companies that use LMS for training and selling courses. A variant of such LMS systems is the Learning Content Management Systems (LCMS). A LCMS provides the ability to customize a course for various target groups while maintaining course history and versions. This eliminates duplicate development efforts and allows for the rapid assembly of customized content.

The basic architecture behind the World Wide Web lacks the capacity to provide a unified intelligent framework required for the implementation of effective eLearning systems. A lot of research work is currently focusing on resolving this issue.

Figure 1 illustrates a traditional web-based eLearning framework that uses a web browser as interface. Users can access learning objects through learning environments either compatible or incompatible with SCORM (Sharable Courseware Object Reference Model) [15]. Learning objects are small reusable piece of content relevant to the learning process. Examples of learning objects include online exercises, further reading, and assessment test. These learning objects are directly linked to multimedia learning resources such as online lecture, presentation slides and reference documents.

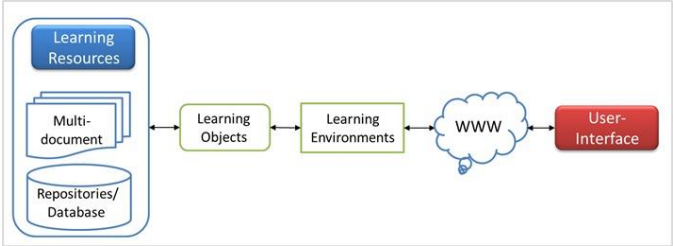

Figure 1: Architecture of the traditional web-based eLearning framework.

2.3 Why Learning Outcomes?

The focus in traditional education is what the educational institution provides to the learners. In contrast, Outcomes-based education is a recent model that has been adopted in the

education sector worldwide. The idea is that the educational system is based on goals or so-called Learning Outcomes which in essence specify what the learners should achieve by the end of the course. Learning outcomes (LO) are descriptions that state what learners should acquire in terms of knowledge and skills by the end of a course or program.

2.4 Why Ontology?

Ontology is an accurate specification of a set of concepts. The term is borrowed from metaphysics, where an ontology is a systematic account of the nature of being. Essentially, ontology can be constructed from a set of entities or things and the relationship of these concepts to one another within a scope of knowledge.

An ontology for the eLearning activities can be structured in various ways, but every ontology includes a dictionary of terms, and explanations of how the terms are interrelated. This structuration will result in a sound tool for the learning process. The ontologies constitute conceptual descriptions of the content as they help to identify suitable items and relationships in each knowledge domain [16], [17].

Users are then able to assimilate, integrate and use these constructs to describe the semantics of processes in the system. Ontologies can also be used to define the operations and other facilities in the system such as structure and communication. Furthermore, ontologies provide a structured representation of knowledge, enabling the alignment of educational content with competency requirements [18].

2.5 Why Semantic Web in eLearning?

Work on the semantic web has paved the way to the development of a new type of web sites where data can be meaningfully processed by computers [19]. Nowadays, most web ontologies are encoded using the Resource Description Framework (RDF) and its extensions Web Ontology Language (OWL) [20] for describing resources on the web, metadata schemas and ontologies.

In eLearning systems, it is vital to be able to keep the conceptual structure of the content for the learners to comprehend the concepts they are learning and thus understand the subject of a given course. Furthermore, the Semantic Web can be used to reinforce semantic interoperability of eLearning components by allowing composition, combination and reuse of various learning materials and elements.

Since the Arabic learning environment requires knowledge and learning contents in different forms, there is a need for semantic-based annotation of the eLearning design, and adapted delivery of the eLearning material.

2.6 Why Semantic Metadata for eLearning System?

There are new technologies for describing characteristics of learning objects in eLearning systems, based on the concept of metadata. Metadata are data about data i.e. metadata are structured information that describe and provides information about other data. In eLearning, metadata describes learning objects. For instance, learning objects can be text, multimedia, objectives, tools, and users. In the context of eLearning, the basic idea of metadata is to describe learning objects by labeling them based on the meaning of their content so that it will be possible to organize them into meaningful groups that can be accessed by the various users.

It is essential to perceive that the metadata must be comprehensible for both the human and the machine and will establish the necessity part of the components of the eLearning and communication system.

3. RELATED WORKS

In this section, we first relate the research and development work accomplished so far using the Arabic language and point out some of the drawbacks in eLearning systems. Secondly, we go over some of the recent work which has inspired the current research on intelligent eLearning based the semantic web.

While most of the established educational websites worldwide are developed in the English language, more and more educational websites are developed in many other languages in general, and particularly in the Arabic language. The most popular educational platforms and portals in the Arabic language include Riwaq Arabic platform[1], Edraaq[2], Naf'ham[3], Tamkeen[4], Nadrus[5], Zadi[6], Hasoub[7], Maharah[8], Doroob[9], Arabic Khan Academi[10]. Nevertheless, when it comes to the Arabic language, many challenges related to linguistics have to be addressed. Furthermore, although modern web technologies are applied, many eLearning systems in the Arabic language have some rather major drawbacks and disadvantages. These disadvantages include, limited number of search fields, relatively weak searching capabilities (many rely on Google search), websites designed for a single or limited number of programs, limited interaction and communication services.

Reference [21] reviewed in detail the technical requirements for semantic web applications for eLearning and ICT applications. Reference [12] discussed the challenging context to reach more effective learning. Reference [22] proposed a design method for transforming UML to semantic description using RDF-based technology.

[1] https://www.rwaq.org/
[2] https://www.edraak.org/
[3] https://www.nafham.com/
[4] https://tamkeen.academy/
[5] https://nadrus.online/
[6] https://zadi.net/
[7] https://academy.hsoub.com/
[8] https://www.maharah.net/
[9] https://www.doroob.sa/ar/
[10] https://ar.khanacademy.org/

Web intelligence along with Artificial Intelligence in education are examined in [23]. This work suggests that with web intelligence, automated detection of educational web content and services can be provided. For instance, course material can be presented based on the most recent related content from the web and learners' and tutors' activities can be automated. Two metadata models are proposed in [24], content model and annotation. This work also presents a framework to support various services in collaborative learning environments. A learning organizational memory system is proposed and discussed along with the adopted ontologies [25]. The memory is document-based and suitable for eLearning applications. A framework for personalized eLearning in the semantic web is proposed in [26]. The authors explore the use of a logic-based approach and applies a rule-based query language for automatic generation of hypermedia structures. Educational Semantic Web is thoroughly discussed in [27]. The authors introduce a modular semantic and service-based framework along with ontology-driven authoring tools. The authors also claim that the challenge in this area of research is to support user-friendly, structured, and automatic authoring tools. A comparison study between Adaptive Hypermedia and Semantic Web is presented in [28]. The authors show how to utilize features of an Adaptive Hypermedia authoring framework in the Semantic Web. An architecture for eLearning services is described in [29]. The architecture provides semantic-based services, in particular, different ways to obtain information by means of web services. Other previous research studies have successfully investigated ontology and semantic-based methods for grid-based eLearning systems [30], [31], and context-aware semantic eLearning systems [32].

Some recent studies on the integration of semantic web technologies include deploying translators [33] and using ontology-based matchmakers [34].

4. PROPOSED SYSTEM ARCHITECTURE

The concept of learning object has been one of the main aspects to consider in examination of eLearning systems. However, we believe that using learning objects to provide courseware to users is limited to giving a static view of eLearning scenarios. eLearning systems should provide support for learners to participate in critical analysis, to discover the most appropriate knowledge and understand new academic contents. To achieve this goal, a framework based on both learning objects and semantic technologies is proposed in this paper. The framework supports state-of-the-art learning processes. The framework allows to develop powerful learning platforms that provides all the necessary information on a given subject in one single repository and allow learners to communicate through various communication channels such as video sessions and discussion forums, and exchange course material by different means such as textbooks, slides, tutorials, exams, and assignments. Three interfaces are provided in the proposed framework, for learners, tutors, and system administrators. The users access services, repositories, and databases through these interfaces. Figure 2 shows the proposed eLearning framework. It illustrates the proposed services that will provide intelligent features to eLearning. The framework is composed of modules and software agents. It includes three modules: resources, services, and user-interfaces. In each module, several software agents are defined. The users of the system, including the learner, the tutor and the administrator benefit from the services in the different modules, through the user-interface module.

The challenge when providing intelligent features through services is for the software agents to deal with Natural Language Processing in general and Arabic language in particular.

The eLearning system includes the following services:

- Registration/authentication
- Semantic search
- Transliteration system
- Question answering system
- Intelligent tutoring system
- Recommender system
- Notifications management
- Text classification/categorization
- Exam setup and marking/grading
- Content annotation
- Dynamic content and resource management

Framework services support the semantic web in order to structure, reuse and compose courseware and learning material. The semantic web enhances user interaction by allowing for precise content retrieval through well-defined ontologies. Also, the framework services are provided with the knowledge representation in the various learning subjects.

In addition to the learning information flow, two new components are added to the proposed framework to bring in additional intelligence in the eLearning process. These components are personal learning assistant as an intelligent personal agent, and semantic context model.

The proposed framework introduces a new flexible learning architecture design in which the learners take more responsibility in their learning engagement compared to the traditional classroom model in which the tutor determines the learning material to be absorbed by learners.

In the proposed framework, the learners establish their own study plan and have access to a wide range of semantic technologies such as annotation management. On the other hand, tutors are relieved from the task of management of learning material. The role of the tutor turns into focusing more on the production of independent pieces of course materials that are properly annotated so that they can be retrieved by semantic services.

Services interact with resources to subscribe to appropriate ontology. One of the main advantages of the proposed semantic eLearning framework is that students do not have to search for courses and related material from different sources unlike in current eLearning systems. Another advantage is that the semantic services monitor the ongoing activities in the background to identify and suggest appropriate services based on the learner's preferences. The learner is prompted to accept or reject the suggestions.

The proposed framework also includes an ontology mapping function as shown in Figure 2. The ontology mapping and related issues are one of our short-term objectives.

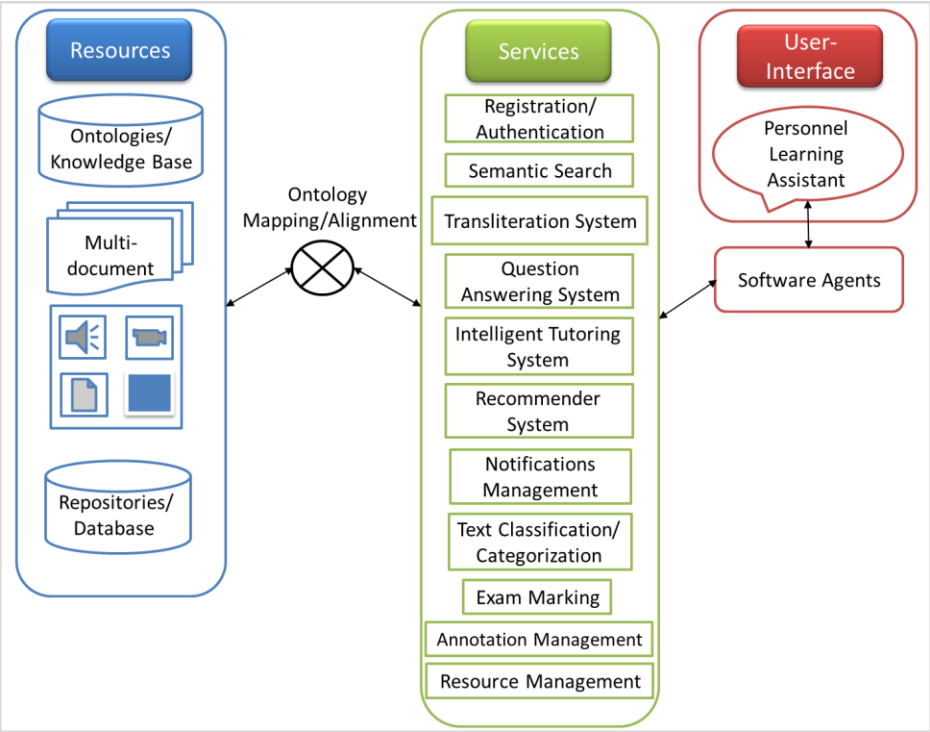

Figure 2: Proposed Intelligent Semantic eLearning Framework.

5. SEMANTIC SEARCH BASED ON METADATA

In this section, we describe how one of the services in the proposed framework works, namely the semantic search [35], which is performed based on metadata. First, we describe the metadata used and how it is implemented by annotating the content. Secondly, an illustrative scenario is given in order to describe the semantic search process in the proposed framework.

5.1 Content Annotation

In contrast to traditional course management, ICT implementation within the education sector requires to store, maintain and use educational resources through technology-based systems, particularly web-based systems and databases. This necessitates reorganization of educational resources by converting them into formats that are adequate for use in ICT platforms. In this context, appropriate ICT-based concepts and techniques include the use of metadata to organize content into reusable tagged objects that can be used to access and control the flow of information in the system. Nevertheless, metadata abstraction can be inefficient if not properly defined, for example weak or irrelevant results can arise when conducting search operations on specific course material if the metadata is inadequate. For instance, metadata descriptions should not only consider pedagogical practices but also socio-cultural ones.

Figure 3 shows examples of metadata elements used in the semantic search approach. In this approach, the main elements are system login, course syllabus, teaching approach, grading policy, communication between eLearning system users, help service, course announcement, among other facilities for instructors and learners. These metadata provide the arrangement for the ontology-driven eLearning system. It helps tutors, learners, and system administrators to compose, control and maintain the course material.

Figure 3: Samples of Metadata Elements for the Semantic Search Approach.

The population of the databases can be entered manually or by using machine learning techniques on text classification.

5.2 Semantic Search Scenario

The scenario is as follows. Assume a learner is interested in a topic area such as "Morphological Analyzer". The traditional search operation (keyword-based) would return all the course materials related to this topic by applying the string-matching technique. Nothing is returned if there is not any matching. In contrast, by using the ontological relations that hold between the topics of the different courses, we can identify which course has the same topic (Morphological Analyzer in this case) and then search for the different resources in the course portfolio repository of the identified course. The results of the latter search are then included in the results of the initial search as possible interesting, related topics or subjects to the learner.

The difference between the semantic search and the keyword-based approach is that the semantic search relies on a structure of interests which is constructed based on the predefined ontology. The structure of interest contains the most common types of information that can be found in an LCMS.

6. CONCLUSIONS AND FUTURE WORK

The Internet and its eLearning applications have become an integral part of today's education system. We believe that more work is needed to analyze and develop a new generation of intelligent LCMS. We have discussed semantic eLearning and proposed a semantic-based framework architecture for intelligent eLearning. The services offered by the proposed eLearning framework that serve both learners and tutors are presented. An illustrative scenario for the semantic search based on metadata has been presented.

The integration of ontology-driven and semantic web technologies in eLearning systems will enhance personalized learning experiences and optimize educational processes. This framework facilitates the creation of intelligent systems that can adapt to individual learner needs, thereby improving engagement and outcomes.

Clearly much more work is needed in semantic-based eLearning. Future work may include implementing an eLearning system based on the proposed framework, including services such as question-answering system for information retrieval and to test learner's level of understanding.

More services can then be added to the framework, such as allocation of learning contents given the learner's level. Another short-term objective is to further investigate ontology mapping and alignment. Our objective is to implement eLearning systems based on the proposed framework for Arabic-speaking learners. Such systems will require support from research on Arabic Natural Language Processing.

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