AN AGENT-MEDIATED APPROACH TO eLEARNING

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Abstract

The confluence of new technologies and the increasing adoption of standards are pushing eLearning to the forefront of web-based initiatives. Agent technology is seen as a critical factor in knowledge acquisition in semantically rich environments, as exemplified by the Semantic Web. In addition the development and delivery of learning content is facilitated by the adoption of eLearning standards. In this paper we consider an eLearning framework where the learning process is mediated by software agents and supported by a knowledge base on learner profiles and skill maps. The roles of the agents are closely associated with the different stages of the learning process. The proposed approach is put into perspective through a brief discussion of some of the challenges that eLearning development is facing.

Key Words:
eLearning, agent technology, metadata

1. Introduction

eLearning, often defined as Internet-enabled learning, has emerged as an answer to the increasing need to create, foster, deliver and facilitate personalised learning anytime and anywhere. eLearning is set to benefit from the confluence of market forces and advanced technologies. It is increasingly argued that organisations should embed eLearning programmes in their processes in order to cope with the volatility and the velocity of today's markets. Investment in eLearning can enhance an organisation's agility. On the technological side, the promotion of semantically enriched environments is seen as a way of dealing with information overload and initiating accurate searches. The availability of machine processable information can usher in the deployment of agents. This initiative is supported by the introduction and the adoption of eLearning standards.

In this paper we present an eLearning framework that brings together these technologies. The paper is organised as follows. Section 2 gives a brief introduction to the learning process. Section 3 introduces eLearning standards. Section 4 deals briefly with metadata and ontologies. Section 5 describes the mediating role of the agents in the eLearning framework. Section 6 presents some eLearning issues and Section 7 concludes the paper.

2. The learning process

The learning process is designed to create an interactive environment between learner and learning content (courseware), through the mediation of an agent, real or virtual. This process takes place within a specific organisational context, and is aimed at facilitating competence acquisition. It consists of four main phases:

1. Training needs analysis (TNA): specification of learning objectives.
2. Curriculum design: selection and organisation of courseware (learning content creation).
3. Curriculum delivery: courseware delivery using appropriate media.
4. Curriculum evaluation: conformance of curriculum design and delivery to learning objectives; conformance of new competences to learners and organisational needs.

Within a traditional setting, the learning process is instructor-centred and presents some distinctive characteristics [1]. The TNA is often informal, *ad hoc*, performed at group level or non-existent. The instructor is responsible for the design and delivery of an undifferentiated curriculum. The learning path is linear, predetermined and static, to a large extent. The course is delivered at set times and depends on the availability of the instructor.

Although these features may not conform to the central tenets of eLearning, a traditional, human-mediated approach presents many advantages. As the instructor is responsible for the whole curriculum, the learning process is likely to be consistent and focused. Curriculum delivery is usually interactive, and minor adjustments can be made dynamically. If the course is made up of many units, there is usually a smooth transition between the units, and the learner is faced with the same 'user model' and mode of delivery. An instructor-centred approach has the added benefit that, in interactive sessions, all learners benefit from the feedback given to an individual learner.

An agent-mediated approach to learning is designed to preserve the advantages of a traditional approach, and to remove or avoid its drawbacks. It is also aimed at satisfying eLearning requirements and enhancing the learning process by exploiting web-based technologies and eLearning standards.

3. eLearning standard requirements

eLearning standards are essentially concerned with the specification of learning content, also called learning objects, and their manipulation. A learning object or shareable content object (SCO) in the SCORM (Sharable Content Object Reference Model) vocabulary is defined as a stand alone content built around one or more learning objectives [2].

IMS (Instruction Management System) has emerged as one of the de facto standards for eLearning content management. IMS provides a number of advantages that makes it attractive as a standard. It enables interoperability and the exchange of learning content between learning management systems (LMS), and is widely accepted as an XML standard for eLearning. One of the fundamental functions of IMS is to 'enable the development of products and services that share a common foundation' [3]. This requirement for interoperability was articulated along the specification of five main areas:

- Enterprise, for sharing data and information about learners and courses.
- Content packaging, for creating and sharing reusable content objects.
- Metadata, for describing learning resources for search and discovery.
- Question and Test Interoperability, for constructing and exchanging tests and assessment information.
- Learner, for organising learner information to satisfy different needs.

SCORM is seen as the convergence of many efforts at standardising learning content, including IMS. Conformance to SCORM standards has significant implications for curriculum design and development. Any SORM-compliant courseware should run on any SCORM-compliant learning management system, such as WebCT. This requirement constrains the relationship between SCO's; a SCO cannot link to another SCO or access its data. The main consequence of the design of a SCO as a self-contained unit is the separation of concerns between navigation within a SCO, and navigation between SCO's, which is the responsibility of the LMS, and ultimately the course developer. This restriction is, however, necessary for the achievement of the four goals of the SCORM framework: reusability, interoperability, accessibility and durability.
Reusability: ability to disaggregate a SCORM-compliant course into its constituent learning objects or SCO's, and use them to create new courses. This requires a specification for all resources in the learning content.
Accessibility: ability to search and discover relevant learning objects. This requires semantic enrichment and metadata tagging.
Interoperability: SCORM-compliant courseware should run on different SCORM-compliant LMS (horizontal interoperability).
Durability: a SCORM-compliant object should run on different versions of an LMS (upward compatibility or vertical interoperability).

The SCORM approach to the achievement of these goals is to specify a run-time environment for every SCORM-compliant course. One common thread that runs through the compliance with eLearning standards, in general, and SCORM, in particular, is the provision and manipulation of context specific and context independent metadata. Accessibility is facilitated and enhanced by conformance to the IEEE LOM/IMS Learning Resource Model, which covers nine categories of information. Among these the most relevant for the search, discovery and selection of learning content are the educational, contextual and relational information categories.

4. Metadata-based environments

It is widely recognised that one of the prerequisites for a successful framework for creating relevant, customised and effective courseware is the ability to filter and select learning content, based on its metadata. eLearning can be defined as a metadata-based initiative, where access to metadata presides over the various stages of the learning process. It can also be seen as an integral part of the drive towards the establishment of semantically rich environments. This trend is finding its full expression in the promotion of the Semantic Web and related technologies [4]. Such an environment is set to encourage the deployment of agent technology and the manipulation of ontologies. Web services [5] have emerged as a technology that is strongly motivated by the notion of a Semantic Web. These XML-based technologies promote the use of lightweight databases, while the characteristics of XML make it suitable for representing and manipulating ontologies.

Although many consider metadata tags as a significant step towards a wider adoption of eLearning, concerns were, however, expressed about their limitations. Among these the lack of standard vocabularies and the lack of formal semantics are considered as major barriers to interoperability [1]**.** Ontologies can provide a way of expanding the scope of eLearning. An ontology is defined as a shared conceptualisation, and consist of definitions of concepts and their relationships [6]. The main advantage of ontologies is that they "interleave formal semantics, understandable to a computer with real world semantics, understandable to humans" [7].

5. Agent mediation in eLearning

The eLearning process defines a loop that starts with the identification of training needs, followed by curriculum design, then implementation and finally delivery. The loop is closed by an evaluation of the process. Agent technology is a key enabler of the whole process.

5.1 Agent technology

Although the notion of agent has presented workers in AI with a major challenge, there is, however some consensus around 'the weak notion of agency' given by Wooldridge and Jennings [8]. An agent is defined as a hardware-based or a software-based computer system that is autonomous, reactive, proactive, and has social ability. Reactivity is a necessary requirement for an agent to be able to respond to stimuli and to interact with the outside world by observing it and operating on it. Autonomy and pro-activity are the two features that distinguish an agent from a mere object, and underline the knowledge level at which agents operate. While autonomy enables an agent to function without direct intervention from other agents, pro-activity emphasises the fact that an agent is goal-directed and can take the initiative. Finally, social ability refers to the communication and interaction between agents.

An agent is endowed with the ability to possess a mental model of the outside world and to reason about it. This deliberative behaviour is modelled by a set of mental categories. The Belief, Desire and Intention (BDI) mental model has become increasingly popular and has been used in many applications [9, 10]. Beliefs, desires and intentions, as mental categories, form the basis for a mental state. The beliefs represent the information that the agent believes is currently true. This information can be on the agent itself, other agents or the environment. The desires or goals are the states that the agent wishes to achieve. An intention involves the selection of a particular plan and a commitment to its execution.

5.2 Agent-based framework

Agents can contribute significantly to eLearning by supporting many of the functions provided by instructors, and by enhancing the learning process. The introduction of agents was motivated by three factors:

1. They are needed to provide support for functions that normally require human intervention. They can deal with complex issues.
2. They can improve the learning process, and satisfy eLearning requirements, such as speed, responsiveness and differentiation.
3. They are also introduced in order to capitalise on the semantically annotated environment. They are able to search, filter and select information effectively.

The different phases of the eLearning process: training needs analysis, search and discovery of learning content, courseware organisation, courseware delivery and the evaluation of the eLearning process itself are all associated with agents. An agent is allocated to each phase of the process and may perform many tasks. The whole process is supported by a knowledge base of user profiles and competences. Agents can also ensure congruence of goals across the different stages.

5.3 Training needs analysis

This stage is critical to the success of the learner's experience since it initiates the eLearning process and conditions to a large extent the subsequent stages. It involves a number of complex tasks because it is designed to identify the absence of competences (or the need for competences), and to map this need to a specification of learning objectives. This may require advanced AI techniques and research in learning psychology.

The TNA should produce a precise specification of the requirements. This objective can be facilitated by maintaining and accessing ontologies and a knowledge base of user profiles and competences. It is worth noting that there is convergence, at this level, between the TNA and many knowledge management functions, especially the skill gap analysis and the skill map management. Furthermore, the learning process needs to be relevant to the (semantic) context of the sponsoring organisation [11]. The role of the agent at this level is to generate a set of learning objectives. This task is facilitated by the availability of ontologies.

5.4 Search and discovery of learning content

The search and discovery of learning content is aimed at satisfying the learning objectives. The learning content may be held locally or remotely on eLearning repositories. Web Services provide a useful framework for the search and the discovery process. In common with eLearning standards, these services are XML-based technologies. SOAP (simple Object Access Protocol) acts an a simple transport protocol, WSDL (Web Services Description Language) is used to describe services, WSFL (Web Services Flow Language) is for composing services and UDDI (Universal Description, Discovery and Integration) for discovering them. Web services can contribute to the on-the-fly creation of courses [12].

The search for learning content may involve interacting with intelligent repositories. Agents are required to direct and supervise the search for learning content, negotiate acquisition and thus interact with other agents by exchanging ontologies. Agent communication languages (ACL) can be accommodated by XML and SOAP, in particular [13]. The search process can also be refined by keeping track of recent developments in a particular field, and accessing the corresponding learning content. The selection of material can be guided by three types of information: educational, contextual and relational. More specifically, an agent may use a number of criteria:

Compliance with standards: support for interoperability and reuse.

Cost: access to material may not free, although many institutions are allowing access to their repositories.

Substitutes: existence of similar courseware elsewhere may indicate maturity and enhance availability.

Granularity: smaller learning content material will facilitate personalisation, but may add complexity to the aggregation process.

Dependency: it may not be desirable to select learning content that requires too many prerequisites.

Reliability: effectiveness of learning content and rating of course developers.

Consistency: the educational category of learning content can be used to ensure some pedagogic consistency between the basic learning objects.

This search process can be facilitated by agents. Agents can reduce information overload and therefore reduce work by taking into account user preferences and competences [14]. The role of the agent at this stage is to take the set of objectives identified in the previous phase and to search for adequate learning content.

5.5 Courseware organisation

The discrete units gathered in the previous stage need to be structured into a coherent whole, in order to satisfy the learning objectives of the TNA. A dependency graph is generated in order to determine the learning path. The graph embodies dependencies between nodes that stand for learning objects, and therefore learning outcomes. These may correspond to aggregate learning content. An agent can perform this function by taking into account the learning objectives, the learner's profile and competences, and more specifically the relational information of the learning content. From this information it is possible for the agent to generate a number of dependency graphs, potentially with different learning objects, that represent equivalent learning paths. The agent may use the learner's profile and possibly organisational constraints to select the most suitable graph for the learner.

An additional responsibility of the agent is the support of the local LMS in the specification of the navigation between learning objects. This assumes, of course, that the framework is SCORM-compliant and that the learning object is responsible for its internal navigation.

One further enhancement to courseware organisation is the inclusion into the graph of substitutes and supplementary information, in order to make it more responsive to the needs of learners. This design phase can benefit from the software engineering discipline [15]. The role of the agent associated with this phase is to select learning content and to generate a learning dependency graph.

5.6 Courseware delivery

The learner's profile and competences can be used by agents to determine and personalise the mode of delivery of the courseware. Innovations in this field have been introduced by Cisco where delivery technologies for a variety of media types were pioneered and developed [16]. Agents can ensure that learners are presented with the same consistent user model throughout the navigation. Some pedagogic consistency can also be achieved.

By far, however, the most important function of the agent at this stage is to supervise the delivery process, and to monitor the performance of the learner [17]. Unsatisfactory progress in a particular course or lack of suitability of learning material may be met with corrective action by the agent, and may lead to a dynamic restructuring of the learning path. The supplementary information that was collected during graph generation may be called upon to adapt and optimise the acquisition of new competences. In this context agents can act as assistants [18]. The knowledge base would be updated to reflect the need for change and the changes, if necessary. The corresponding agent is responsible to overseeing the delivery of learning content.

5.7 eLearning process evaluation

Quality control processes should ensure that the eLearning programme is cost-effective and suitable. It may involve formative and summative evaluation. The evaluation of the eLearning process may be performed over a long term period and should involve two aspects:

- Determining to what extent the courseware organisation and delivery conform to the learning objectives, as identified by the TNA. The approach may have to be adapted to new conditions.
- Establishing to what degree the new competences fulfil the needs of the learner.

6. Discussion and further work

The development of personalised eLearning courseware faces many challenges. The complexity that is inherent to an accurate identification of training needs or skill gaps may limit the impact of eLearning programmes. At a lower level, the search for learning content rely on access to well specified ontologies. The lack of shared vocabularies may prevent the acquisition and integration of relevant learning courseware. There is also some concern about letting learners select their own material without adequate supervision or information. The integration of material may lead to difficulties for the learner. Is there adequate pedagogic compatibility between the assembled learning objects? Do they all present compatible interfaces? Is there a seamless transition between learning objects?

There is increasing evidence from many research programmes that agents can assist in meeting the objectives of eLearning programmes [19]. The provision of a knowledge base to which references are frequently made by agents can ensure that the learning process is learner-centric. Agent technology can alleviate some of the shortcomings of the eLearning process. This may be accompanied, however, by added complexity; it requires a level of sophistication at the knowledge level. Further work could also extend to making the system more responsive and adaptive.

The research programme outlined here is at an early stage. Discrete stages are being investigated before a full integration can be achieved. We have been experimenting with graph dependency generation using a local repository, for which SCORM-compliant learning content is being developed. Currently, the focus of our work is on search and discovery of learning content.

7. Conclusion

This paper has presented an agent-mediated approach to eLearning. It was argued that the availability of metadata and ontology-based systems has created an environment favourable to the deployment of software agents in the various stages of the learning process. Although agents can operate effectively at various levels of the eLearning process, the generation of a useful specification from the training needs analysis phase and its translation into an effective curriculum presents a significant challenge.

References

[1] Stojanovic L., Staab S. and Studer R., eLearning based on the Semantic Web, *WebNet2001 - World Conference on the WWW and Internet*, Orlando, Florida, USA, 2001.

[2] SCORM Content development course, *http://www.scorm.tamucc.edu/scorm/home.html*.

[3] Getting Started in IMS, *http://www.imsproject.org/pressrelease/ims_getting_started-20020729.pdf*.

[4] Berners-Lee T., Hendler J. and Lassila O, The Semantic Web, *Scientific American*, May 2001, 29-37.

[5] Preece A. and Decker S., Intelligent Web Services, *IEEE Intelligent Systems*, January/February 2002, 15-17.

[6] Gruber T., A Translation Approach to Portable Ontology specifications, *Knowledge Acquisition 5*, 199-220.

[7] Ding Y., Fensel D., Klein M. and Omelayenko B., The semantic web: yet another hip? *Data & Knowledge Engineering 41 (2002)*, 205-227.

[8] Wooldridge M. and Jennings N., Intelligent Agents: Theory and practice. *The knowledge Engineering Review*, *10(2)*, 1995, 115-152.

[9] Rao, S. A., & Georgeff. M. P., BDI Agents: From Theory to Practice, *Conference Proceedings of 1st international conference on multiple agent system*, 1995, 312-319.

[10] Huber M. J., JAM: a BDI-theoretic mobile agent architecture, *Proceedings of the Third International Conference on Autonomous Agents. ACM.* (1999), .236-43.

[11] Adelsberger H., Bick M., Korner F., Pawlowski J.M., Virtual Education in Business Information Systems (VAWI)–Facilitating Collaborative Development Processess Using The Essen Learning Model, *Proceedings of the 20th ICDE World Conference on Open Learning and Distance Education*, Dusseldorf, Germany, April 2001.

[12] D. Fensel and C. Bussler, The Web Service Modeling Framework WSMF, *Electronic Commerce Research and Applications 1(2002)*, 113-137.

[13] Moreau L., An Agent for the Grid: A Comparison with Web Services, *Proceeding s of the 2nd IEE/ACM International Symposium on Cluster Computing and Grid*, Berlin, May 2002, 220-228.

[14] Guan S., Ngoo C.S. and Zhu F., Handy broker: an intelligent product-brokering agent for m-commerce applications with user preference tracking, *Electronic Commerce Research and Application 1(2002)*, 314-330.

[15] Douglas I., Instructional design based on reusable objects: applying lessons of object-oriented software engineering to learning system design, *31st ASE/IEEE Frontiers in Education Conference*, Reno, USA, October 2001.

[16] E-Learning Content Management vs. Content Delivery, *http://business.cisco.com/servletwl3/FileDownloader/iqprd/88758/kbns.pdf*

[17] Maes P., Agents that reduce work and information overload, *CACM Vol. 37 No. 7*, July 1994, 31-40.

[18] Maglio P.P. and Campbell C.S., Attentive Agents, *CACM Vol 46, No. 3*, March 2003, 47-51.

[19] Garro A. and Palopoli L., An XML Multi-Agent System for e-Learning and Skill Management, *http://www.isi.cs.cnr.it/isi/garro/masel.pdf*.