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Semantic Web and Agent-Based Technologies in Adaptation of e-Learning Systems

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Summary

The paper discusses some basic applications of semantic web and agent-based technologies to the adaptation of e-learning systems. The material is presented in the following order. Firstly, the basic principles underlying e-learning, adaptive e-learning and agent-based technologies are clarified, and then we discuss the well known in the literature example how agent-based technologies can be implemented for the area of e-learning systems, viz. the multi-agent system of Athabasca University for course personalization.

1. Introduction

According to Wikipedia e-Learning is a computer based training which incorporates technologies that support interactivity beyond what would be provided by a single computer (Wikipedia). An e-Learning system is a computer system that enables e-learning. The main objective of e-learning systems is therefore to enable individually subscribed to learning services to be delivered to their associated users whenever they request them, and wherever the users are, in a customized form that matches their profile (Lin, 2004).

There is the growth diversity of users of e-Learning systems that differ by their knowledge, goals, and preferences. It is currently argued that the most of the software should be personalized (for example, Margoulis et al, 2004). Automatic personalization may greatly enhance user productivity, but it requires advances in customization (explicit, user-initiated change) and adaptation (interface-initiated change in response to routine user behavior and personal preferences) (Weld, 2003).

User-adaptive tutoring systems have already proved to be more effective and/or usable than non-adaptive systems (Fink, 2000). The significance of the e-Learning system personalisation arises from psychological and pedagogical aspects. The e-Learning system has to be used by a much wider variety of students than any "standalone" educational application (Brusilovsky, 1999). According to (Brusilovsky, 2004) personalized e-Learning is a key element for next generation educational programs. e-Learning systems adaptation allows to maximize the potential of each learner by providing individually personalized learning experiences. Adaptive e-Learning systems provides the user with dynamically composed courses which are tailored to his individual’s specific needs, experience, prior knowledge, computing environment, connectivity and communication preferences (Dagger, 2005).

According to Paramythis (2004) “learning environment is considered adaptive if it is capable of: monitoring the activities of its users; interpreting these on the basis of domain-specific models; inferring user requirements and preferences out of the interpreted activities, appropriately representing...
these in associated models; and, finally, acting upon the available knowledge on its users and the subject matter at hand, to dynamically facilitate the learning process”.

The improvement of human-computer interaction process in the web-based learning systems can increase the effectiveness of the learning and solve some pedagogical, psychological problems of e-learning concerning the issues of user-teacher feedback, learning material presentation (Brusilovsky, 1998). There are some advantages of adaptive e-Learning systems from the standpoint of its development and using different learning strategies: reduced complexity (in the strategy design process), increased efficiency (both in the time taken to design the adaptive learning strategies as well as in learning how to design learning strategies) and decreased costs associated with such compositions, the reusability of the strategies (Dagger, 2005). Both e-Learning tasks and human-computer interaction problems make an intense interest for the subject of this report.

Historically, almost all web-based adaptive learning systems inherit from intelligent tutoring systems and adaptive hypermedia systems (Brusilovsky, 1999). The most known adaptive e-Learning systems are InterBook (Brusilovsky, 1997) and AHA (De Bra, 1998, 2003). They on the whole or partially implement all techniques of learning systems adaptation (adaptive presentation, adaptive navigation, and adaptive collaboration) on the base of the user modelling. The user knowledge characteristics, his goals and interaction parameters such as frequency of the help system usage, visiting of additional information under the special hyperlinks, are included to the user models of these systems. The achieved results have demonstrated the advantages of the e-Learning systems adaptation, but the systems have many limitations. One of these limitations is that the system does not take into account any psychological user’s peculiarities. Adaptation techniques are also successfully used in such web-based systems as recommender systems, route advisors, eCommerce systems, big internet portals.

The multi-agent technologies is one of the main directions in adaptive systems research. It seems to be very a promising research and practical approach in the development of adaptive e-Learning systems. It is widely argued that multi-agent architectures are more flexible and scalable than other architectures. On the base of the use of multi-agent technologies the learning materials, course structure and user interface of e-Learning system could be adapted. Now there is growing number of agent-based technologies applications for web-based system such as e-Commerce, Online Recommendation Systems, Mobile Navigation System. We argue that the outcomes from this kind of research areas could be used in studies and development of agent-based adaptive e-Learning systems.

2. Adaptation Technologies in e-Learning System

There is distinction between adaptive and adaptable systems (Fischer, 2001). The difference is in the organisation of the adaptation process. Adaptation in the adaptable systems is performed by user (with substantial system support), who change the functionality of the system. Adaptive systems support dynamic adaptation by the system itself to current task and current user. Adaptive web-systems belong to the class of user-adaptive software systems. A distinctive feature of an adaptive system is an explicit user model that represents user knowledge, goals, interests, and other features that enable the system to distinguish among different users (Brusilovsky, 2002). An adaptive system collects data for the user model from various sources that can include implicitly observing user interaction and explicitly requesting direct input from the user. In this paper we analyze the class of adaptive e-Learning systems and application of agent-based technologies for this adaptation.

According to Brusilovsky (2002) the adaptation effect in the adaptive web-based systems is limited to three major adaptation technologies – adaptive content selection, adaptive navigation support, and
adaptive presentation. The adaptive content selection implies the system to adaptively select and prioritize the most relevant items when the user searches for relevant information. This technology has come from the field of adaptive information retrieval and is associated with a search-based access to information. The adaptive navigation support implicates the system to manipulate the links (for example, hide, sort, annotate) during the user navigation session. This adaptation technology was introduced by adaptive hypermedia systems (Brusilovsky, 2001). Adaptive navigation is supported in such learning systems as ELM-ART (Brusilovsky, et al., 1996), InterBook (Brusilovsky, 1996), AHA! (De Bra, 1998), KBSHyperbook (Henze, 2001), ActiveMath (Melis, et al., 2001), and ELM-ART (Weber, 2001) supports several variants of adaptive link annotation. MLTutor (Smith, 2003) uses link sorting and generation. The adaptive presentation supposes the system to form content of a particular page adaptively. In a system with adaptive presentation, the pages are not static but adaptively generated or assembled for each user (Brusilovsky, 2004). The examples of web-based systems that supports adaptive presentation are:

- ActiveMath (Melis, et al., 2001) that provides one of the most advanced existing examples of adaptive presentation.
- ELM-ART (Weber, et al., 2001) that demonstrates a special form of adaptive presentation - adaptive warnings about the educational status of the current page.
- MetaLinks (Murray, 2003) that demonstrates the use of adaptive presentation for "narrative smoothing".

Paramythis (2004) recognizes the following types of learning environments adaptation: content discovery and assembly, adaptive course delivery, adaptive interaction, and adaptive collaboration support, which are shortly described below.

The first category, Content Discovery and Assembly, applies adaptive techniques in the discovery and assembly of learning materials (learning content) from distributed sources and repositories. The adaptive component of this process lies with the utilization of adaptation-oriented models and knowledge about users typically derived from monitoring, both of which are not available to non-adaptive systems that engage in the same process (Paramythis, 2004).

The second category, Adaptive Course Delivery, tailors a learning course to the individual learner. It constitutes the most common and widely used collection of adaptation techniques applied in learning environments today. The main intentions for this approach are time and effort economy, compensating for the lack of a human tutor (who is capable of assessing learner capacity, goals, etc., and advising on individualized “curricula”), improving subjective evaluation of courses by learners, etc. (Paramythis, 2004). The examples of adaptations in this category are: dynamic course (re-)structuring; adaptive navigation support; and adaptive selection of alternative (fragments of) course material (Brusilovsky, 2002).

Adaptive Interaction adapts the user interface, without adaptation of the e-learning materials content. The examples of adaptive interaction are: adaptation of position of the presented information; adaptation of the graphical/colour schemes and font sizes; adoption at the lexical level of interaction (to user preferences, requirements or (dis-)abilities); adoption at the syntactic level of interaction (by reorganization or restructuring of interactive tasks); adoption at the semantic level of interaction (by using of alternative interaction metaphors).

Adaptive Collaboration Support adapts communication used in learning processes. The main goal of this type of adaptation is to facilitate the communication/collaboration process, and ensure a good
match between collaborators. (Paramythis, 2004). This is an important dimension to be considered as we are moving away from “isolationist” approaches to learning, which are at odds with what modern learning theory increasingly emphasizes: the importance of collaboration, cooperative learning, communities of learners, social negotiation, and apprenticeship in learning (Wiley, 2003).

3. Adaptive e-Learning System Architecture

Adaptation process in e-Learning systems is usually organized in a classical way (Brusilovsky, 1999) (see Fig. 1). The special adaptation tool of e-Learning system gets information about the user, executes user modelling and performs adaptation on the base of the existent adaptation rules.

There is no general architecture of adaptive e-Learning systems now. The developers and researchers suggest their architectures. The most common components of adaptive e-Learning systems are user models/user profiles repository, adaptation engine that includes user modeling engine and adaptation rules engine. On the Fig. 2 the multi-model architecture of adaptive e-Learning system, suggested by Dagger et al. (2003). Within this architecture the adaptive engine interacts with the learner to build a personalized learner model. Adaptive engine interacts with and interprets the learner model, the content model, the narrative model, the candidate content groups and any other required models to produce the adaptive personalized course model for the learner. The personalized course model is transformed to create the personalized course for the learner (Dagger, 2003).

In (Vasilyeva, 2005) the general architecture of adaptive e-Learning system is proposed (s. Fig. 3). The arrows on the figure emphasize information flows most relevant to the adaptation process. On the left hand box in the figure the main collaborators bringing in their expertise are named. Among the main
contributing participants of any e-learning system are students, teachers, knowledge engineers, usability engineers, system architectures (developers), administrators, and psychologists.

On the right hand box in Figure 3 the main data repositories needed in the system are named. Beside the learning material itself the system needs several types of knowledge and meta-knowledge to be able to adapt effectively and efficiently. In figure these include assessment data, user models/profiles, data log, and knowledge about adaptable characteristics. In the middle part of Figure 3 we have named beside the adaptation engine itself some other engines offered to main participants for keeping repositories updated.

The general architecture (Figure 3) is planned to be able to offer the types of adaptation suggested in (Paramythis, 2004) (See Section 2.1). For content discovery and assembly knowledge about users is collected by monitoring and further included in the user models/profiles repository using software tools and meta-knowledge created by the system architects, knowledge engineers, and teachers. Meta-knowledge for adaptive course delivery is mainly acquired from teachers, and usability specialists. The role of adaptive interaction meta-knowledge is to point out the context in which the adaptation should be performed. The meta-knowledge for this type of adaptation is mainly formed on the base of knowledge, which could be acquired from usability specialists, psychologists, and from the experimental studies of the interaction between the user and the system. Adaptive collaboration support type of adaptation emphasizes the “collaboration” approach to learning by using communication between multiple persons, cooperative learning, communities of learners, social negotiation, and apprenticeship in learning (Paramythis, 2004). For this type of adaptation the meta-knowledge could be acquired from psychologists, usability engineers, and communication experts.

![Figure 3. The general architecture of adaptive e-Learning system (Vasileyva, 2005)](image-url)
4. Agent Technologies

An agent is a computer system that is situated in some environment and that is capable of autonomous action in this environment in order to meet its design objectives (Wooldridge, 2002).

![Diagram of agent and environment](Image)

*Figure 4. Agent (Wooldridge, 2002)*

The above figure gives an abstract view of an agent. In this diagram the action output is generated by the agent in order to affect its environment.

In a distributed adaptive learning environment, agents can be seen as software systems that perform their tasks while taking into account the available resources and skills. The resources include human users, other agents, information, and data. Therefore, all the agents can be divided into several categories: (a) personal agents, (b) task agents, and (c) regulatory agents (Lin, 2004).

A *personal agent* is a virtual representation of a human user performing some tasks in a distributed adaptive learning environment (Lin, 2004). It can be seen as a system consisting of several components, which act together to perform required functions. A personal agent has a memory function that stores the user’s preferences, which may be explicitly indicated by the user or learned from past experiences. Similarly, the personal agent also learns from interaction with other agents. The memory module is able to “forget” information that is not used, avoiding storage overload. The personal agent is able also to prioritize various tasks set by the user (Lin, 2004).

A *task agent* is supposed to perform certain specific tasks, such as providing services, knowledge, and information resources, and also providing coordinating and communicating with the other agents. The task agent also has a monitoring and learning ability that allows it to update its own information. The task agent is supposed to be a “common resource” shared by many users (Lin, 2004).

A *regulatory agent* is supposed to serve for setting standards and auditing. On the one hand, the international regulatory agent sets standards for the baseline requirements to which each agent must comply. In turn, personal agents and task agents that constantly monitor the external environment, update their respective baseline requirements to include the latest standards. On the other hand, the regulatory agent audits the localized regulatory agents, which in turn, audit personal agents and task agents. The scope of the audit services includes the accuracy of an agent’s baseline requirements, the program’s integrity (the audit will look for any virus infection), etc (Lin, 2004).

Agent Interactions

The above agents are able to interact with one another. There can be the following types of interactions: Personal Agent – Personal Agent, Personal Agent – Task Agent, and Task Agent – Task Agent (Lin, 2004).

Communication between several personal agents is important, since they can learn not only from their...
past errors, but also from the experiences of other personal agents. Moreover, personal agents can collaborate with one another on similar tasks. For effective collaboration personal agents need to coordinate their actions with various task agents.

From time to time personal agent needs to interact with one or more task agents in carrying out its assignment. At this point their can be two situations: 1) a personal agent knows the task agent and contacts it directly; 2) a personal agents does not know the task agent and uses web services for contacting the task agent (Lin, 2004).

5. Using Intelligent Agents for Adaptation E-Learning

In this section we would like to overview an example of how the multi-agent paradigm can be implemented for the case of adaptive e-Learning that can be found in (Lin, 2004). Athabasca University (Canada), where students take courses in asynchronous way (grouped or individual), serves as an e-Learning environment. Most of the students work and have a personal need to improve their careers. The students have also a long-term study plan and prefer a flexible and individualized study environment. A significant percentage of the students would like to have access to the courses using mobile devices and Internet. According to the above user requirements, a multi-agent architecture for implementing an e-learning system was proposed by Lin (2004). The developed system offers course personalization and supports mobile users connecting from different devices. The main components of the system are supposed to be (Lin, 2004):

1. **User profile repository**. For each user, the system maintains a profile that contains the learner’s model, user’s preferences concerning learning styles, interfaces, and content display.

2. **Device profile repository**. For each device, the system maintains a profile of the features and capabilities useful for providing the e-learning service (screen size, bandwidth limit, colors, resolution, etc.). Some features that can be automatically detected by the system (operating system, browser, plug-ins) are not stored in the repository but are integrated with the profile when initializing the terminal agent.

3. **Learning object repository**. This contains the course’s teaching material defined as learning objects (Wiley, 2000).

4. **Course database**. For each course, the system maintains two knowledge structures: the course study guide and the course study plan.

5. **Multiagent system composed of stationary and mobile agents**.

A high level vision of the system architecture is presented at Fig. 5:
Figure 5. Architecture of multi-agent adaptive e-learning system (Lin, 2004)

Profile Manager Agent

According to (Lin, 2004) the profile manager is implemented as a stationary agent. It manages the knowledge related to the students and all defined devices (terminals). The main tasks of the profile manager supported in the system are:

- Performing user authentication.
- Acting as a central register, where each new student must be registered.
- Managing and assuring the consistency of the databases containing the student and device profiles.
- Receiving service requests from terminals and giving access to the user profile data.
- Initiating and sending the user agent and terminal agent to the remote device.
- Checking the versions of the user agent and the terminal agent that reside on remote terminals and automatically downloading any necessary updates.

Course Provider Agent

According to (Lin, 2004) this is a stationary agent that manages the knowledge about courses and teaching strategies. The main tasks of the course provider are:

- Providing an interface for defining learning objects and course knowledge (study guide and study plan).
• Receiving service requests from terminals and giving access to course data.
• Generating the course study guide and study plan based on the user profile and the teaching strategy.
• Packaging the course teaching material according to the user profile and device profile.
• Initiating and sending the tutor agent and terminal agent to the remote device.

User Agent

According to (Lin, 2004) this is a mobile agent that carries and manages a local copy of the user profile (user’s preferences and student’s model) to the remote terminal. The main tasks of the course provider are:

• Providing the tutor agent and terminal agent with the user information (profile, identification).
• Managing and synchronizing user profile duplication with the central server.
• Providing the local personalization of the course material — in collaboration with the terminal agent and the tutor agents, the user agent insures the display of the course material according to the user’s preferences and the terminal’s capabilities.

Tutor Agent

According to (Lin, 2004) this is a mobile agent that manages the course delivery to the roaming user. The main tasks of the course provider are as follows:

• Carrying and managing the course material and study plan.
• Providing a personalized learning service to the learner based on his or her model and learning style.
• Insuring the adaptation and packaging of external course content— Because the system is open to third-party providers, external course material will need to be converted to the required format and adapted to the user and device profiles. In collaboration with the user agent and the terminal agent, the tutor agent insures the necessary adaptation and conversion.
• Synchronizing the course content with the server.

Terminal Agent

According to (Lin, 2004) this is a mobile agent that maintains the terminal profile of the corresponding device and insures the display of services according to the user’s preferences and terminal’s capabilities.

6. Conclusions

We believe that adaptation of e-Learning systems is a promising approach to the e-Learning environments development. Adaptation could allow increasing the efficiency of learning and human-computer interaction in virtual learning environments. Despite the usual increasing of the resources that are need for development of adaptive systems, the adaptation could decrease the costs for development for e-Learning systems. For example, using of content discovery and assembly adaptation could decrease time that is needed for learning materials development.

The multi-agent technologies are likely to be very promising research and practical direction in development of adaptive e-Learning systems. Multi-agent architectures are more flexible and scalable than other architectures. The course adaptation in e-Learning systems can be carried out either on the
server or client side, in respect to the user’s needs. The multi-agent architecture can support a dynamic adaptation both of learning materials and user interface.

7. References

17. Lin, F., Ally, M. (2004). Designing Distributed Environments with Intelligent Software Agents,


