Adaptive Knowledge Exosomatics for E-Learning

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ADAPTIVE SERVICES FOR ALL IN E-LEARNING

In this article, e-learning is considered as "learning activities enabled by computer and networks (Internet and Intranet)." The distributed learning environment and especially the Web-enabled technologies make asynchronous learning possible via Internet. With the development of the Internet and the increasing needs of life-long learning, e-learning is becoming one of the most important applications on the Internet.

The e-learning community has already come to the consensus that knowledge sharing is a basis of e-learning. To reach this goal, the standards of learning resources based on metadata and their application guides have been addressed by many organizations. Also, learning resources exchanges (MIT OKI, 2004; Nejdl et al., 2001) and learning systems based on the existing standards are studied practically (Atif, Benlamri, & Berri, 2003; Karagiannidis, Sampson, & Cardinali, 2001; Microsoft, 2003; Paramythis & Loidl-Reisinger, 2003).

Learning is a complicated cognition-based activity. Apart from knowledge sharing, "adaptive services" is another factor in enhancing e-learning systems. For learners, it means gaining adaptive learning services appropriate for their abilities and experiences. These services include adaptive interaction, adaptive course delivery, content discovery, assembly, and adaptive collaboration support. In the past, two important techniques have been studied for adaptive learning: Intelligent Tutoring Systems (ITSs) and adaptive hypermedia. ITSs support adaptive learning through artificial intelligence technologies. A typical ITS system consists of several interdependent cooperative components: student model, pedagogical module, domain knowledge module, and communication module (Woolf, 1992). Adaptive hypermedia provides user interaction by supporting adaptability of content selection, navigation, and presentation (Brusilovsky & Maybury, 2002).

By nature, e-learning is a cooperative activity involving stakeholders including teachers, learners, instructional designers, publishers, organizations, parents, and so forth who have different goals and cognitive background. An e-learning system is required to meet the heterogeneous needs and provide "adaptive services for all." For example, educational researchers agree that providing domain knowledge for learning environments is difficult and time consuming, since it is complicated to search, authorize, and organize learning content based on their knowledge of domain, pedagogy, and information science. Adaptive services of authoring learning resources are very important for the instructional designers. Parents need to access their children's learning records and to take part in some learning activities easily. Publishers need to store, manage, and publish learning resources in consistent ways. Adaptive authoring tools (Brusilovsky, 2003) are starting to attract attention: the European Union Open Consultation of Sixth Framework Programs put forward "pedagogic standards, pedagogic and organizational tools" (Bottino, Kearney, Lefrere, Lindquist, & PROMETEUS Community, 2001). These are good start-ups for adaptive services for all.

AVENUES TO COGNITION-BASED ADAPTIVE SERVICES

How do we improve cognition-based adaptive services in e-learning systems? This is a new challenge for long-term research. We suggest the following

avenues from the views of system design based on artificial intelligence technologies.

Multi-Faceted Knowledge Sharing Based on Ontologies

Adaptive services for all needs multi-faceted knowledge (summarized in Table 1) to be shared in e-learning systems. Apart from domain knowledge (learning content or courseware), there are other kinds of important knowledge, mostly related to epistemology, psychology, pedagogy, and artificial intelligence.

If the above multi-faceted knowledge is standardized or formalized and shared, then an e-learning system will be an open environment to enable adaptive knowledge services, support introduction of novel educational approaches, and improve collaborative learning processes.

Formal description of multi-faceted knowledge includes syntax and semantics. Syntax adopts Web information description languages such as XML and RDF. Semantics will consider the functional relationships among concepts (the knowledge elements) and reasoning ability based on the knowledge of cognition and pedagogy. For example, LOM, LRM, and SCORM are designed to describe and standardize domain knowledge objects, which has XML banding in its syntax, but their semantic applications are designed according to the Semantic Web architecture (Nilsson, Palmer, & Naeve, 2002). Furthermore, these data models themselves need to be extended for adaptive application (Atif et al., 2003; Conlan, Hockemeyer, Lefrere, Wade, & Albert, 2001; Sampson, Karagiannidis & Cardinali, 2002).

As a method for formal descriptions of the shared knowledge, specific ontology is adopted by the Semantic Web community (Decker et al., 2000). Ontologies will also play a crucial role in e-learning knowledge sharing and adaptive reuse (Mizoguchi & Bourdeau, 2000). Ontologies are generally defined as an explicit, formal representation of a shared conceptualization of a particular domain (Studer, Benjamins, & Fensel, 1998). The most typical kind of ontology for the Web has a taxonomy and a set of inference rules that can be implemented as textual Web page documents using a formal language. Distributed open ontologies, with standard ways of representing and standard interfaces for open-accessing (Sidney, Bai, & Walt, 2002) will provide a commonly agreed understanding on an issue for all stakeholders and services on the Web in e-learning applications. Some abilities of ontologies have been studied: using "competency ontologies" and Semantic Web services to deliver learning objects to learners in a corporate environment (Woelk, 2002), using "concept ontology" as "knowledge route" (Sampson et al., 2002), and using "task ontology" in authoring tools (Jin, Chen, Hayashi, Ikeda, & Mizoguchi, 1999). In order to support multi-faceted knowledge sharing based on the techniques of ITS and adaptive hypermedia, we propose a system framework for e-learning knowledge ontologies and their relationships which is described in a UML class diagram in Figure 1.

In this framework, several kinds of interoperable e-learning distributed open ontologies are building blocks to support adaptive services for e-learning applications. For instance, a domain concept ontology is a resource about knowledge concepts; it acts as a

Table 1. Multi-faceted knowledge in e-learning environment

Domain knowledge	The organized learning contents (courseware) made by instructional designers.
Strategy knowledge	The strategies on how to manage learning contents and control instruction processes.
User model knowledge	The personal information and its management method for all the partners.
Other knowledge	Knowledge about the environment, application interaction, etc.