Knowledge Management for Agent-Based Tutoring Systems

Ping Chen

Computer and Mathematical Science Department

University of Houston-Downtown

One Main Street

Houston, TX 77002

Telephone: 713-221-2764

Fax: 713-221-8086

Email: chenp@uhd.edu

Wei Ding

School of Science and Computer Engineering

University of Houston-Clear Lake

2700 Bay Area Boulevard

Houston, Texas 77058-1098

Email: ding@cl.uh.edu

Phone: 281-283-3871

Fax: 281-283-3869

KNOWLEDGE MANAGEMENT FOR AGENT-BASED TUTORING SYSTEMS

ABSTRACT

As the educational field is becoming increasingly technology-heavy, more and more educational systems involve on-line or interactive training and tutoring techniques, and lots of educational information becomes available via Intranet and World Wide Web. Managing large volumes of learning information and knowledge is one of the crucial issues for these educational systems as appropriate knowledge management is the key to more effective and efficient learning. The chapter discusses that an intelligent agents system could be successfully applied to the educational field and how knowledge management techniques plays a very important role.

KEYWORDS: Knowledge Management, Agent Technology, Educational Technology, Computer-Assisted Education

INTRODUCTION

Computer technologies are making progress rapidly and becoming more and more specialized, and lots of different fields have benefited from newly invented and powerful computer technologies, so it is not a surprise that education adopts more and more computer technologies and students and learners will need and use computers in a lot of courses and labs. New technology integrated into the education or tutoring system can enhance the access to knowledge and improve the efficiency of knowledge transferring to learners. But such integration often requires additional training for its users to get familiar

with a new learning environment before they can actually benefit from these technology advances; otherwise, new technology will confuse and distract, instead of helping, its users, and slow down the learning process. Agent-based tutoring systems can overcome such technical obstacles between knowledge and common users, and make users to be able to focus on information and knowledge that they are interested in and try to learn. Unlike the traditional tutoring systems which are characterized by a stand -alone approach, i.e., autonomous and complete in itself, an agent as a software entity can work continuously and autonomously, in a particular environment usually occupied by other agents, and is able to interfere in its environment in a flexible and intelligent way without demanding constant human interference or orientation. An agent working continuously for long time periods should be able to learn from experience, and in sharing its environment with other agents it should be able to communicate and cooperate with them. Therefore, an agent can have the following attributes: reactiveness, autonomy, cooperative behavior, communication ability at knowledge level, interference competence, temporal continuity, personality, adaptability, and mobility. And all these properties will make agent-based tutoring system more effective and efficient (Silveira, 1998).

Agent-based human-machine interaction was first commonly used in 1930’s, such as autopilot systems etc.. Such agents aided or performed some automatic and simple tasks that otherwise human beings have to perform. A human operator will perform a supervisory task (involving cognitive processing and situation awareness skills) instead of old manipulation tasks (usually involving sensory-motor skills) (Sheridan, 1992).

The use of software agents as intelligent assistant systems was proposed (Alchourron, 1985) that would facilitate human-computer interaction to transfer information, as well as human-human interaction for better understanding through new software technology. Adoption of agents in an educational and tutoring system is natural since information and knowledge transferring is the most important part in learning. Agents can enable the understanding and learning of various kinds of concepts since they involve active behaviors of the users. They enable users to focus on the content and index content to specific situations that they will understand better. To be specific the advantages of using software agents in education may include:

- Customized learning environment for individuals
- Unified learning environment
- Integration of local and remote resources
- Transparent process to make users focus on knowledge to be convoyed, not how to use the tutoring tools.

In this chapter we will talk about an agent–based tutoring system architecture design and how to manage knowledge and "knowledge about knowledge" (meta-knowledge) in an agent-based educational environment.

BACKGROUND

Learning is an active, interactive and constructive social process. Technology, especially computer technology can help learning greatly. Initially the learning technology focused on individualized instruction, i.e., standalone tutoring, universal environment for all students. Current view training and education environments must support customized

inquiry-based learning and collaboration, and such an environment has the following advantages over the old learning technologies:

- Intelligent tutoring systems have explicit tutoring models and domain knowledge that can serve each individual in a more customized and efficient way.
- Interactive learning systems enable the student to manipulate cognitive artifacts from several perspectives or viewpoints (Norman, 1992).
- Cooperative learning systems provide students with access to other people's ideas and concepts, which make it possible to exchange, discuss, negotiate, defend and synthesize viewpoints (SIGCUE, 1992).

Also the advances in network technology make learners far away can communicate with each other more efficiently. A web-based tutoring system is not only technically possible but also mostly desirable.

Another technical advance comes from object-oriented technology. An instructional technology called "learning objects" currently is the most popular choice in the next generation of instructional design, development, and delivery, due to its potential for reusability, generativity, adaptability, and scalability (LTSC).

Learning objects are elements of computer-based instruction based on the object-oriented paradigm (Wiley, 2002). The Learning Technology Standards Committee use "learning objects" to describe these small instructional components and provided a working definition:

> "Learning Objects are defined here as any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning. Examples of

> technology-supported learning include computer-based training systems, interactive learning environments, intelligent computer-aided instruction systems, distance learning systems, and collaborative learning environments. Examples of Learning Objects include multimedia content, instructional content, learning objectives, instructional software and software tools, and persons, organizations, or events referenced during technology-supported learning."

Since learning is for learners to get and understand information and knowledge from knowledge bases. How information and knowledge is acquired, stored, represented, accessed, updated and transferred in an educational environment will determine how effective and efficient the educational system and learning process will be. According to Taylor (Taylor), Knowledge Management is about using models, methods, structures, and techniques for better management and organization of resources. Knowledge Management as an ongoing management process is to be embedded in the knowledge-based system. The purpose of Knowledge Management is to enable effective usage of information and human resources and based upon this to act intelligently and be more flexible, and as a result to be able to improve basic processes of research, production, and maintenance.

Implied in the term Knowledge Management is the notion that every knowledge-based system possesses knowledge and needs mechanisms to gather, store, manipulate, and manage it in order to accomplish the most effective usage of the knowledge.

Karl Wiig describes four main knowledge flows functions (Wiig, 1995):

- *building* knowledge is achieved through learning, importing knowledge from existing resources, or creating new knowledge through research and development;
- *storing* the knowledge in memory, knowledge bases, books or other written materials, videotaped instruction material and *organized* in order to be available for specific purposes;
- knowledge is *distributed* by assembling relevant knowledge from different sources and distributing it to places of use, and is *pooled* by assembling different persons in a team and by exchanging knowledge between them;
- knowledge is *used* when it is needed to apply it to work objects. Value is added by using knowledge to make products or to provide services. Here the value of knowledge is realized.

Diana and Aroyo used the following diagram to show where these function are fulfilled (De Diana):

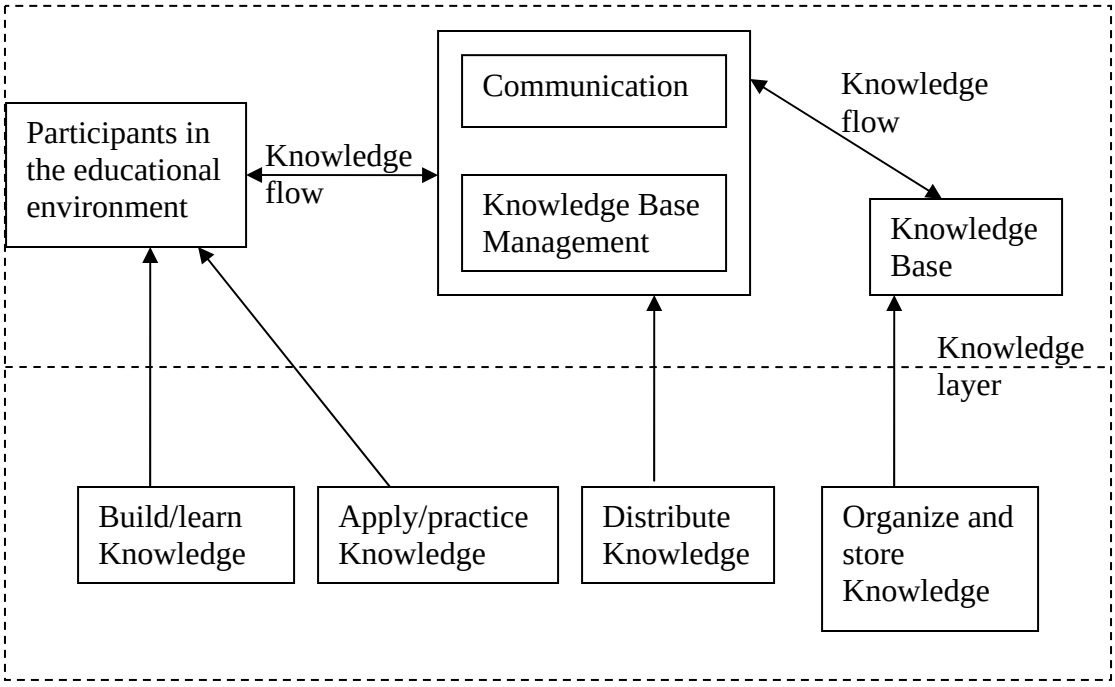

Figure 1 Knowledge Layer in Networked Education

The approach in Figure 1 does not specify the details about communication and Knowledge Base management modules, and there may exist many different ways to implement them. The main advantage of using an agent-based approach in educational systems is that the central control function is devolved to different agents, and there is no need for a centralized control process to oversee the communication and interaction and database management among learners, interface and databases. This results in a robust system with better performance, more availability and a more customized student learning session (Bruff, 2000).

Diana and Aroyo (De Diana) pointed out that the main tasks and knowledge involved in education can be divided into two levels: tasks and knowledge related with learning and instructional processes and tasks and knowledge (knowledge about knowledge, which is knowledge about how to manage knowledge in the first level) related with the organizational and management level. This two-level model reflect the necessity to separate the knowledge to be learned from managing knowledge (meta-knowledge), and we will talk more about it in the following sections.

MULTI-AGENT-BASED EDUCATIONAL ENVIRONMENT

Wooldridge and Jennings gave one of the most comprehensive definitions of agents in (Wooldridge, 1994):

> "a hardware or (more usually) a software-based computer system that enjoys the following properties: *autonomy* - agents operate without the direct intervention of humans or others, and have some kind of control over their actions and internal state; *social ability* - agents interact with other agents (and possibly humans) via

some kind of agent-communication language; *reactivity*: agents perceive their environment and respond in a timely fashion to changes that occur in it; *pro-activeness*: agents do not simply act in response to their environment, they are able to exhibit goal-directed behavior by taking initiative."

We call agents used in an educational environment as education agents. The role of the educational agent is to provide task-related feedback and assistance to the learner and guide the learner through the learning process and reach their learning goals. In an educational environment usually multiple agents are involved and play different roles. And there are two problems to be considered in designing and building educational agents:

- Reusability: reusing agents in different kinds of systems and environments.
- Interaction: in an environment containing multiple educational agents, tutor agents interacts with each other and customizes their behavior based on the behavior of other agents in the environment.

Norrie and Gaines proposed the following agents in an agent-oriented model for an education environment (Norrie, 1995):

- **Knowledge Agent** has knowledge in a particular area.
- **Knowledge Server Agent** stores, retrieves and manages knowledge, and answers queries and provides information by inferring or reasoning using the stored knowledge bases.
- **Interface Agent** serves as an interface to learners, and monitors and learns from the user's actions and then functions as an intelligent assistant.
- **Coach or Tutor Agent** will provide guidance to assist in the learning process.

- **Mediator Agent** coordinates the activities of other agents and resolves conflicts between them.
- **Knowledge Management Agent** provides the high-level coordination of knowledge activities, such as creation, assembly, manipulation and interpretation of knowledge, within either an individual or collective project.
- **Information Search Agent** searches specific information and to sends the results back to learners.
- **Directory Agent** points to an appropriate agent, service, or resource.
- **Mentor Agent** is envisaged as acting in a rather analogous way in the learning environment, as a kind of coach for the higher-level strategies of learning.

Bruff and Williams illustrate an agent-based intelligent tutoring system architecture with the following three kinds of agents:

- **Knowledge Management Agent** responds to requests from other agents.
- **Student Agent** is assigned to each student and manages the evolution of a student model which may include a representation of the student's current knowledge and history about the topic and the student's personal goals and preferences, etc.. The student agent's goals will typically vary from student to student, or from time to time even for the same student and can be customized by a third party such as a human tutor. These goals determine the learning strategies and tasks to be used during a given learning session. The learning strategies together with the database describing the current state of the agent and its knowledge about the student's capabilities will largely control the agent's behaviors, that is, a customized agent for each individual learner.

- **Inference Agent** provides preset inference mechanisms, which include a group of agents, such as deduction, abduction and induction agent, belief revision agent, possibility reasoning agent, nonmonotonic reasoning agent and theory extraction agent, etc..

In general all these three kinds of agents can be called *tutoring agent*, which is able to interact and cooperate with the student for tutoring and learning purposes. In the above architecture we have three kinds of agents and assigns more functions to each agent, and actually a lot of different architectures has been proposed for an agent-based tutoring system, for example, Silveira and Viccari (Silveira, 1998) proposed several different agents, *Curriculum manager* (the agent responsible for registering and controlling the curriculum attended by the students), *Agent communicator manager* (the agent responsible for the agents society administration and for controlling the communication between them) and *Interface communication (*the agents responsible for peer-to-peer communication between the student's environment and the network environment) and *Presentation manager* (the agent responsible for the browser control in the student's environment). In a finer model every tutoring agent will perform only one tutoring function. All these functions should be performed as session-based. Tutoring functions may include (Morin, 1998):

- Select a subject element,
- Format and present a subject element,
- Format and present an explanation of a subject element,
- Compare different concepts,
- Select, format and present an example,

- Answer a student's question,
- Evaluate the student's answer to a system-asked question,
- Send feedback to a student about his answer to a system-asked question,
- Diagnose a student's behaviors,
- Update student model.

Tutoring systems for different courses or topics, or for students with different background may have different preferences or requirements on system architecture (types and amount of agents, their responsibilities and interaction), and there is no existing universal architecture that will fit all. When designing agents for a learning environment we have to understand the requirements of the to-be-built learning system first, the background and goals of its users, then determine the types and amount of agents we need, the interaction among them and assign tasks accordingly.

KNOWLEDGE MANAGEMENT FOR A TUTORING SYSTEM

Knowledge is one principal factor that makes personal, organizational, and societal intelligent behavior possible (Wiig, 1995). Knowledge management consists of activities focused on the organization gaining knowledge from its own experience and from the experience of others, and on the judicious application of that knowledge to fulfill the mission of the organization (Wiig, 1995). In the context of learning environment, such an organization consists of a group of students. These activities are executed by integration of technology, organizational structures, and cognitive-based strategies to convey existing knowledge and produce new knowledge. The critical step is the enhancement of

the cognitive system in acquiring, storing and utilizing knowledge for learning, problem solving, and decision making.

Knowledge management is stated as the management of the organization (an individual student or a group of students in our context of learning environment) towards the continuous renewal of the organizational knowledge base, which may include the creation of supportive organizational structures, facilitation of organizational members, applying IT-instruments with an emphasis on teamwork and diffusion of knowledge (as in groupware) (Bertel). As such, knowledge management is a strategy that turns an organization's intellectual assets - both recorded information and the talents of its members - into greater productivity, new value, and increased competitiveness.

For a tutoring system, obviously we need a framework that can support knowledge management: a framework that offers a computational environment in which well represented knowledge can serve as a communication medium between students and their activities. The indicated framework can consist of a shared knowledge representation and mechanisms for customized routing of knowledge to appropriate students (De Diana).

Models, methods, tools and techniques for effective knowledge management become increasingly available, which is very important for education since learning is a highly interactive process, and different kinds of knowledge are transferred among learners, tutoring systems and human tutors.

An essential aspect of knowledge is that it is contextualized and dependent. This is the reason why knowledge is so difficult to acquire, represent, access and transfer. Bruff and Williams pointed out that intelligent tutoring systems have to provide mechanisms to deal with the following interrelated knowledge-modeling problems (Bruff, 1999):

- Uncertainty of knowledge,
- Conflicts among knowledge,
- Dependency among knowledge,
- The problem of knowledge granularity
- Incompleteness of knowledge, i.e. all relevant knowledge may not be known.
- Fusion of knowledge, where knowledge is merged from different sources, and
- Revision of existing knowledge base when new knowledge is obtained. This new knowledge may be inconsistent with the existing knowledge base.

Knowledge that is uncertain or incomplete may need to be revised as being refined over time. Therefore, revision of a knowledge base is closely related to modeling both the uncertainty and the incompleteness of information. If readers are interested in these topics, more references can be found in further readings section.

Besides the problems of knowledge incompleteness, updating, conflicts, granularity and uncertainty, one of the problems from knowledge modeling in agent-based tutoring system is to deal with different kinds of knowledge. We discuss how to manage these different kinds of knowledge existing in a tutoring system in the following subsections that is mainly based on (Morin, 1998).

1. Domain knowledge (**conceptual and procedural) (DK)**

Domain knowledge is the real knowledge we want to teach to a student and it contains all conceptual and procedural aspects of the knowledge of one topic or area. Different topics or courses may have domain knowledge with different structures. Usually domain knowledge may include concepts and relations among concepts, and often theses relations will organize concepts into a hierarchical

structure, which will help learning process greatly and provide foundation for problem-solving or inferential knowledge. For example, concepts can be basic entities like the binary tree or binary search tree. And there is a “subclass of” relation between them.

2. Problem-solving knowledge (inferential) (PSK)

Problem-solving knowledge is the knowledge that a student uses to learn domain knowledge. It is usually modeled and stored as procedures, and it contains inferential processes used to solve a problem using relation information from domain knowledge (Lelouche, 1997).

3. Tutoring knowledge (TK)

Tutoring knowledge includes information of common student errors and misconceptions, and tutoring knowledge is the most important knowledge since it is the key for us to build a customized learning system for each student, which can deliver appropriate individualized instruction to help students learn more effectively and efficiently. And this ability depends heavily on the availability and accuracy of the information held about the student in the student agent, which holds different types and levels of sophistication of the knowledge and also includes methods to elicit and incorporate the new information into the student model.

Tutoring knowledge usually is session-based since it varies from topic to topic, from student to student and from time to time even for the same student. Moreover, to make a learning process more interesting and efficient, a tutoring system should use a variety of stimuli, such as multimedia techniques, to present a

topic in different ways even to the same student, and to change the ways of presentations of the explanations or answers provided to the student.

FUTURE TRENDS

We believe that agent-based tutoring systems will provide a means of dealing with the knowledge acquiring, revision and transferring that are essential in a learning process. Agents will use a variety of communication and representation modes to help us to understand and make use of course materials or knowledge. We are sure that learning environments employing multi-agents systems allow students, teachers and courseware developers to add flexibility in achieving their learning objectives. To make such a system more helpful, future study may concern the following problems:

- Different architecture design for different courses, topics or disciplines

  Since different courses, topics or disciplines involve knowledge that is very different in presentation or nature, such as history and mathematics, we may need different knowledge management architectures and techniques for them.

- How will Internet technology affect an agent-based tutoring system?

  Modern tutoring systems should be web-based to maximize accessibility. Integration of web technologies needs further investigation on tutoring system architecture and knowledge management.

- Cooperation between an agent-based tutoring system and existing software tools.

  Existing software tools can help development of an agent-based tutoring system greatly and provides insights to a better learning environment. Such cooperation can also help cost reduction.

FURTHER READING

Some researchers (Mizoguchi et al, 1988), (Kono et al, 1992), (Giangrandi and Tasso, 1995) have applied Truth (or Reason) Maintenance Systems (TMS) (Doyle, 1979), (DeKleer, 1986) to overcome conflicts between new and old knowledge. The TMS identifies the conflicts, and some domain specific reasoning system will resolve them. Huang and McCalla (1992), and Huang (1994) developed "Logic of Attention", a variant of the TMS that focuses on the parts of the student model and instructional planner that are relevant to the current sub-goals. Bruff and Williams (2000) proposed an architecture in which the problem of conflicting information is resolved using methods based on the AGM paradigm for belief revision (Alchourron et al, 1985). Bruff and Williams used possibility theory (Dubois, 1992) to address the problems of uncertain information, nonmonotonic reasoning, and default logic (Reiter, 1980) and the formalism (Antoniou, 1996) to process incomplete information and Theory Extraction for fusion. Knowledge granularity has been widely discussed (e.g. McCalla and Greer, 1994). Levels of granularity fit naturally into the agent architecture and can be used to help the agent choose an appropriate plan.

CONCLUSION

In this chapter we discussed how agent technology could be used in an educational environment and how knowledge is managed in such a system. Although many problems remain to be solved, we believe that agents can model and manage knowledge in an

appropriate way and agent technology will be an important step to improve the effectiveness and efficiency of a tutoring system.

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