International Journal of Multimedia and Ubiquitous Engineering
Vol. 1, No. 3, September, 2006

Adaptive Tutoring and Training System Based on Intelligent Agent

Joung-souk Sung[1] and **Doo-hun Lim**[2]
[1]Department of Computer Engineering, BaekSeok College
e-mail : jssung@bcc.ac.kr
[2]Department of Management, University of Tennessee
e-mail : dhlim@utk.edu

Abstract This paper describes an adaptive tutoring and training system based on intelligent agent. The system comprises a set of two main agents: Tutoring Agent and VR Training Agent. We propose an adaptive problem-based tutoring system, that learner with different learning goals and different learning aptitudes are treated differently by allowing each learner a personalized course meeting his/her own learning needs. The training system supports situation-based learning, in which learners learn situations by performing learning tasks in the VR environment. Also, various agents of the system are designed and implemented to control learning processes and to provide learning feedbacks. The aim of this work is to develop a tutoring system with an intelligent Learner Modeler and a VR training system to reinforce learner's learning application performance.

Keyword: Adaptive tutoring, Intelligent agent, Problem-based learning, Situation-based learning

1. Introduction

Currently, agent concepts that satisfy adaptive learning are of interest for many sub-fields of computer science and artificial intelligence. The idea of an intelligent Tutoring Agent that performs the role of a human tutor is being instructed in a wide range of education [1]. Also agents using the intelligent tutors employ synchronous and asynchronous group learning processes to provide feedback [2]. Examples of agent applications widely used in the educational field include personal assistants, user guides, alternative help system, adaptive collaboration learning, intelligent mentoring, and so forth [3].

Intelligent Tutoring Systems (ITSs) have been considered to be a very effective learning method that requires extensive practice for learning [4]. ITSs support individual learning based on the target knowledge a learner is expected to learn and the presumed state of the learner's current knowledge. ITSs provide customized and adaptive learning according to an individual learner's needs, learning behavior, and learning situation in which the learner is involved [5]. One central component of ITSs is a highly flexible and adaptive tutoring role to adequately support learning processes for individual learners [6].

Virtual Reality (VR) has recently appeared as an alternative to conceive intelligent agent based learning systems. Using VR in the school system allows opportunities for learners and teachers to experience a new learning environment. Of interest, existing learning systems have been claimed not to converse as smoothly, intelligently, and in depth as a human. Also, they do not satisfy various learning needs requiring more learner immersion in the learning situation.

We have developed and tested a learner tele-evaluation system based on distributed collaboration environment. In an effort to improve the learner tele-evaluation system using the intelligent tutoring system, we propose an advanced learning system that provides learners with individualized and dedicated feedback based upon an accurate diagnosis of the learner actions and the Artificial Intelligence (AI) techniques that provide some assistance on how the learner should progress. This system develops an adaptive personalized course meeting his/her own learning needs. The system seeks to reinforce the learner's learning performance and can serve as a convenient major step for learning based on intelligent agent.

2. System Description

2.1 System Overview

The proposed tutoring and VR training system is a web-enabled tutoring system that has a centralized architecture and all tutoring functions are performed on the server side. Within the two-domain system (server and client) the actions produced by learners are textual and the amount of information to be sent to the server is small so that the centralized architecture can handle learning events without network burden. In the client side, when learners start an initial learning action, some tutoring/training functions related to the learner action are initiated. The tutoring functions are therefore distributed between the server and the client. Also, the system supports synchronous and asynchronous cooperation among learners, cooperation being achieved either between the learner and the tutor/expert or inside a group of learners interacting with or without the tutor. Fig. 1 illustrates the server and client environment of the system.

Regarding the system process, a learner is required to enter his/her name, which is necessary to establish a session at the beginning of learning interaction. The learner is asked to fill out an online form to determine his/her profile. The session manager requires the Learner Modeler to retrieve a learning model for the learner if there is one or create a new model if it is a new learner. The didactic needs assessment approach used in the system utilizes pattern recognition method by observing learning and communication patterns among learners. During interaction with the system all learner actions are sent to the session manager and linked to the related session by using learner information stored in the student log.

The proposed system can be thought of a tutoring and training system reinforcing learning, evaluation, and

application of learning. This system comprises several learning modalities that combine the traditional learning activities through problem-based learning, creative learning, and situation-based learning.

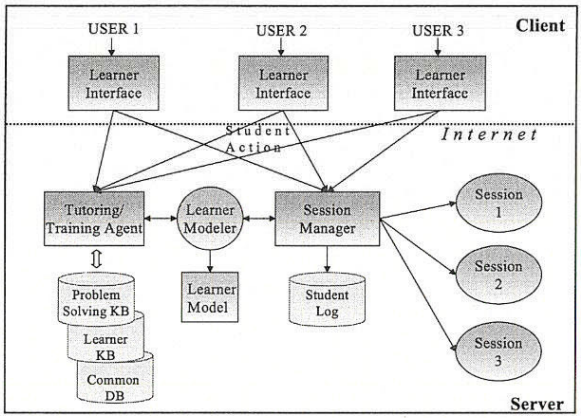


Fig. 1. Overview of the system

The tutoring functions of the system are based on a tutorial question-answer format. It elaborates learning dynamics through Learner Modeler to model learner. Learner Modeling concerns the learner profile about the course to be taught and his/her preferences in terms of the type of media. The Learner Modeling employs question-answer interactions with the system. To build a new course, the system refers to the individual learner's history of previous learning and problem solving processes.

2.2 Learning Modality

In the proposed tutoring/training system, there are three types of learning modality: learner learning, evaluation activities, and training. Learner learning and evaluation activities utilize problem-based method while training utilizes situation-based method. Under the learning modalities, involved activities are learning by listening, problem solving, and example demo. Under the evaluation modalities, evaluation activities are conducted through problem solving, solution analysis, low-level learning application, and feedback. Here the low-level learning application is intended to result in near transfer where learning content is applied to a situation the learner is familiar with.

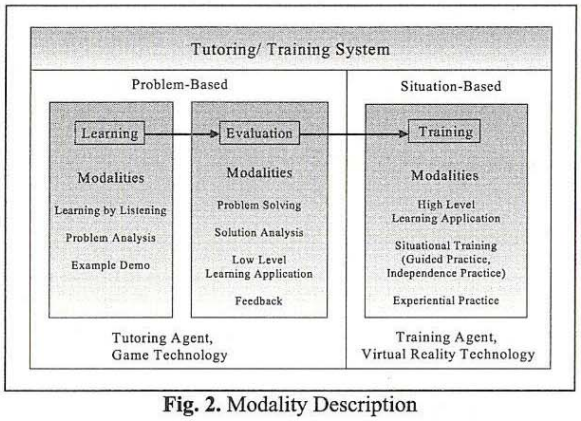


Fig. 2. Modality Description

Training modalities include learning activities such as high-level learning application, guided practice, independent practice, and experiential practice.

Here the high-level learning application implies the application of the learned content to an unfamiliar context.

Diverse learning functions within the Tutoring Agent include setting objectives for learning, motivating learners, giving instructions, giving a specific task, asking questions, answering questions, explaining, illustrating, providing feedback and support, hinting, pumping for more information, summarizing, giving examples, and evaluating student learning. Help or feedback also takes place at this domain in an indirect manner. Agents act as sub-topic experts who have access to problem solving experiences, context sensitive help and advice, and conceptual and procedural tutorials. In order to activate these problem-based learning activities, we employ AI technology and game technology in the system structure.

Training Agent is a VR-based practice system used for learning with various virtual reality concepts. Using VR in the school system to educate and test students allows opportunities for learners and teachers to experience new learning environment. VR can be viewed as a software paradigm that offers one or more learners to explore and interact with a computer generated environment. In order to activate situation-based practice activities, we develop the system using AI technology and VR technology.

3. System Configuration

3.1 System Configuration

The system comprises five components: the agent, the module, the modeler, the communication, and the knowledge base. Fig. 3 illustrates these components and the interactive relationships between them. The interaction behavior specifies how each agent engages with its environment and the diagnosis behavior determines the agent's decision-making process. Firstly we explain the relationships between the system components and the agents. The second describes the functions and roles of the agents themselves.

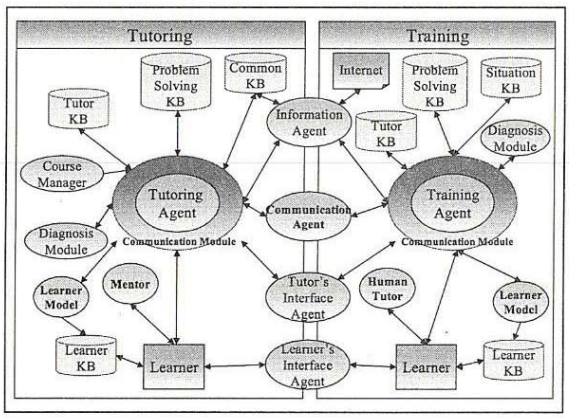


Fig. 3. Configuration of the system

The Tutoring and Training Agent are composed of several sub agents that provide interactive and cooperative functions within the learning system. The two main agents communicate through Communication Agent. The agents use the knowledge base (KB) to provide elicited tutoring/training profile and to retrieve elements from a problem solving KB. The agents deduce correct answers to test questions and provide intelligent

feedbacks and hints to individual learner. The system includes Diagnosis Modules responsible for assessing learners' learning process. These agents and modules are designed and implemented to control synchronous and asynchronous learning processes and to provide learning feedback.

3.2 System Function and Role

The *Tutoring Agent* proposes the most suitable problem to the learner, including learning goals and the level of learning. Also the Tutoring Agent advises learner to select a learning strategy based on its didactical decision process with the learner. To accomplish tutoring goals, it launches a module with an appropriate level through a diagnosis process and, once the diagnosis phase is completed, it prepares interactions with other agents and learners. The Tutoring Agent can give advice on learner behaviors to attain learning goals. Other main functions of the Tutoring Agent include setting objectives for learning, motivating learners, giving instructions, giving a specific task, asking questions, answering questions, explaining, illustrating, providing feedback and support, hinting, pumping for more information, summarizing, giving examples, and evaluating learning. The *Training Agent* is used to support and manage the whole VR environment. It also enhances interactivity and provides more intelligent help to learners. The Training Agent has knowledge about the situations being engaged, monitors the status change of the environment, and informs the learner of the monitoring results. When the learner encounters problems during learning, the Training Agent diagnoses the situation, checks the problem solving KB, and presents the corresponding information. The major function of the *Learner's Interface Agent* is monitoring the learner's actions, notifying other agents when needed, and giving access to system resources. This agent controls the access to the Learner Model and brings to the learner information about the whole learning environment. It also records the behaviors of the learner so that it can learn from these behaviors about what the learner likes and dislikes. It helps the learner log in and log out. The *Tutor's Interface Agent* is an agent associated with the tutor's interface. This agent controls the access to the tutor's KB and brings to the tutor information about the whole learning environment. This agent mediates interface modules related to: communication with other agents, update of new activities to the learners, distribution of such activities to learners, and supervision of work done by learners. The *Information Agent* is responsible for retrieving and filtering information from specified sources that can range from the learning materials and experiences available in the system to the entire Web. The *Communication Agent* controls the communication with other agents, including sending out messages, checking message delivery, and receiving and interpreting message performance. The *Diagnosis Module* is responsible for answering other agents' queries. The strategy employed here is to consider complete solution paths and offer advice only when the learner completes the problem. The Diagnosis Module performs an analysis of the semantic closeness between the learner's answer and the correct answer. Correct answers are already stored in the Problem Solving KB. The tutoring system has the *Course Manager* that represents the target skills and its constituent sub-skills and depicts how they are related. The Course Manager determines which module the learner needs to start when he/she log in to the system by assessing the learner's understanding of the previous learning content or module. For this purpose, the Course Manager asks the learner several initial questions to decide the next learning content to start with. The *Learner Modeler* modifies the learner's profile, the level of knowledge about the course to be taught, and the learner's media preferences for future use. It also creates and updates a Learner Model based on an evaluation of the learner's natural language answers to assessment questions. In this way, personalization of the learning process is improved. The *Learner Model* aims to meet the needs of the learner. The Learner Model is used to see if certain learning content has already been taught to the learner and generates an appropriate learning module for each learner based on the learner's profile. While the Learner Modeler is utilized as an interface agent between the learner and the Learner KB, the Learner Model functions as a DB of the learner information. Two types of information are modeled: the learner's level of knowledge about the course to be taught and the learner's media preferences. The Learner Model is also used to reason about the problem solving behavior of each learner and of the group. It generates tutorial hints to guide group problem solving activities. Generating appropriate tutorial actions requires an assessment of the learner's understanding of the problem domain. The Learner Model is decided by learning structures using data collected from problem-based learning tutorial which becomes the source to determine the learner profile about the progress of learning. The *Learner KB* includes an administrative component responsible for managing the learners such as assigning login names and passwords, managing the learner's profile database, and recording learning experiences. This database is accessed by the Learner Model of each learner and by the Tutoring Agent. In the *Problem Solving KB*, correct answers to learning problems are already stored in the system by the tutor. We built a problem solving KB with multiple choice questions and answers. This agent becomes satisfied when the course classification of problems it represents is present in the learning environment. The combination of the different values these didactical variables can take leads to more or less complex problems, allowing focusing on different aspects of the reflective learning and most important, allowing the expression of different conceptions. The *Common KB* includes a realistic knowledge base and associated exercises to enable an effective evaluation of the potential use of the system within a course. Each tutor has its own specific tutor's knowledge base and also inherits global knowledge from a common knowledge. It also has a common knowledge database, which consists of help and illustration information about a specific course.

4. Tutoring/ Training Agent and Behavior Process

In our proposed adaptive tutoring/training system based on intelligent agent, the Tutoring agents and Training Agents are the driving engine of the system. Their main tasks are to generate appropriate learning feedbacks for learners and provide new learning problems and advanced situations. In this section, we will explain how the Tutoring and Training Agents function and how the behavior process of each agent is implemented.

4.1 Tutoring Agent

A tutoring agent is usually related to Learner Modeling

and didactic decision-making [7]. This agent delivers questions and provides immediate feedback to learners. The Tutoring Agent of this system offers an adaptive tutoring environment, where learners with different learning goals, different preferences, different learning profile, and different learning aptitudes are treated differently, by building a model of learning knowledge and preferences about each learner. In an effort to provide a more verisimilitude, our proposed system is emulating a mentor who analyzes each learner's documented activities to provide feedback. In order to initiate problem-solving activities, the tutor or learner using the system may invoke the Information Agent to perform search of relevant information either from the learning material within the system or on the web. According to the needs of the learner, the tutor can adapt and teach the course again. During the tutoring process help or feedback also takes place in an indirect manner. The Tutoring Agent acts as a sub-topic expert who has access to problem-solving experiences, context sensitive help and advice, and conceptual and procedural tutorials. The proposed system adapts the level and content of learning to individual learner by analyzing the learner's learning profile and preference and presents the needed course content in a desired form of presentation.

The Tutoring Agent controls a problem solver since it is capable of solving both pre-specified problems and the problems entered by learners. The problem solving KB consists of constraints used for testing the learner's solution for syntax errors and comparing it against the system's ideal solution to find semantic errors. It enables the tutor to identify learner solutions that are identical to the system's ideal solutions. More importantly, it also enables the system to identify valid alternative solutions, that is, solutions that are correct but are not identical to the system's solution. Each constraint specifies a fundamental property of a domain that must be satisfied by all solutions. In the system, quiz is randomly generated from a problem solving KB when the learner needs to take the quiz. After submitting his or her answers, the learner immediately receives his or her score with a brief explanation of the answers and a link to the course content where that topic was covered. Immediate feedback and remediation are key components of an ITS to provide appropriate response and reinforcement. Result visualization is followed after interpreting the test result. Also, result visualization is constructed along with the input from the learner. The learner may set up the initial parameters of the problem solving paradigm and interpreting the results. They access the graphical feedback only to verify and correct their proposed solution.

4.2 Feedback diagnosis

In any tutoring system, it is important to consider not only how feedback is given to the learner but also when it is most useful. In the proposed system, the learner has options to choose when feedback is provided. By recording the various diagnoses made during the learner's problem solving activities, the system can evaluate the learner's learning not only based on the present state of the exercise, but considering also the process through which the present state is reached. The feedback mechanism provides a means of controlling the type of feedback provided to the learner. In contrast to the immediate feedback that the system intervenes after each error made by the learner, the final feedback that is given only at the end of the exercise without considering the intermediate steps may cause the learner makes significant errors before there is any intervention. The learner who needs more frequent feedback is most likely to be one who needs more learning exercise for certain learning content. The feedback diagnosis performs an analysis of the learner's answer by calculating the semantic closeness between the learner's answer and the correct one.

4.3 Tutoring Behavior Process

The Tutoring Agent coaches the learners by sharing its expertise in the form of problem-solving KB and pre-packaged tutorials. After each learner's action, the Learner Modeler collects all types of feedbacks, evaluations, and suggested activities, and then applies the conflict resolution strategies to implement an appropriate tutoring action. The feedback and assessment content and activity content messages, along with the acknowledgement messages, provide indirect clues for tutoring. According to the information obtained from the Learner Model, the tutoring process follows several consequent steps. First, after a learner spends some time to solve a learning problem, if the problem does not look familiar, the learner asks the tutor for a hint. Next, after reading the hint carefully, the learner should decide whether a more detailed hint is needed or not. Through this reasoning process, the agent can deduce the correct answers to test questions and provide intelligent feedback and hints to the learner. The Tutoring Agent evaluates the learner's answers and gives specific feedback. In synchronous mode, learner can ask questions about the learning material and learning question at any time, then the human tutor can answer with a relevant reply. The tutoring activities are also connected to the learning profile of the learner. For example, when making suggestions about how to set initial parameters for learning, the Tutoring Agent advises the learner more or less, depending on the learner's profile. During the tutoring process the system selects a problem and compares its solution with that of the learner and then performs a diagnosis based on the differences. After giving feedback, the system reassesses and updates the Learner Model and the entire cycle is repeated. As the system is assessing what the learner knows, it is also considering what the learner needs to know, which part of the course is to be taught next, and how to present the material. It then selects the problems accordingly.

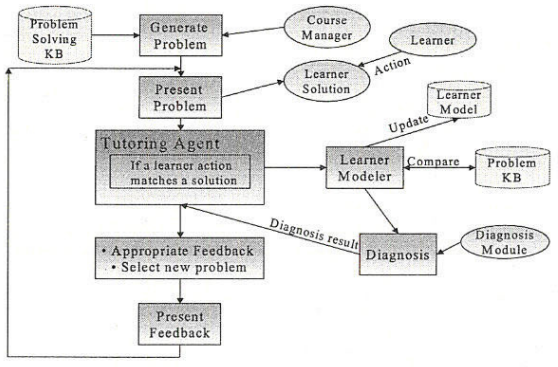


Fig. 4. Process of the tutoring behavior

All learner actions are then sent to the Tutoring Agent. If

a submitted action initiates a solution to the current step, the Tutoring Agent sends it to the Learner Modeler, which diagnoses the solution, updates the Learner Model, and sends the result of the diagnosis back to the Tutoring Agent, which generates feedback. If the learner performs an incorrect action, that action will violate some constraints and the system responds by generating an appropriate feedback message which explains the general principle violated by the learner's action. In tutoring process, feedback can be very detailed by instantiating parts of the feedback according to the learner's action. The Learner Modeler evaluates the learner's solution against the knowledge base and updates the Learner Model. Learner Model is used to select problems of appropriate complexity for the learner, and to generate feedback. The level of feedback is incremented with each submission until the feedback level reaches the detailed hint level. Regarding the level of feedback the system gives the learner the freedom to manually select the level of feedback according to individual needs. Also the system implements rules for generating a variety of tutorial actions including tutoring steps and giving positive or negative feedback.

4.4 VR Training Agent

The system extends the basic VR training paradigm by adding a multimedia component that can be accessed during interaction with the virtual learning environment. The training system should provide the opportunities to experience the process of knowledge application during learning [8]. The system uses a situation-based learning approach to document the range of activities undertaken by the learners. The VR can be viewed as a software paradigm that offers one or more learners to explore and interact with a computer generated environment. Different types of devices allow for learners to perceive and manipulate the visual objects as in the real world. We support that training processes should take place within situation-based learning environment to be more effective. The Training Agent of our proposed system teaches learners procedural tasks in simulated and situation-based VR environments. Each situation contains situational hints and hyperlinks to the relevant theories and definitions that must be learned and applied to complete the situation. The training modalities we implement in the system include situation-based training, advanced level creative learning, guided practice, independent practice, and experiential practice. The VR Training Agent continuously and dynamically adapts the training situation's contents and the available set of actions to the Learner Model and to the training situation's KB (see Fig. 5). In the training system, the Learner Model built by a diagnose process is used to automatically generate, for each learner, an appropriate VR training situation. When a learner's course tracking information and the learner profile are identified, the system generates a new situation. A situation is composed of the situation number, the target course content to study, and the learner profile. The situation-based training is composed of sub situations in three levels; advanced, intermediate, and beginning level. Each course in the situation-based training is initialized with typical situations and is eventually updated with new situations. When a new situation arrives, the system tries to find similar situations in the situation base. The new situation is stored if there is no similar situation and the system considers it relevant [6].

4.5 Training Behavior Process

The situation-based training process provides assistance to learners by presenting them with examples of relevant experience. In the training situation, two kinds of interactions are possible for the learners. First, the learners select a learning situation by clicking on a menu or region in the learning screen. Once select a learning situation, second, the learners select which learning actions to perform. The situation-based Training Agent begins the learning process with prototypical training modalities and accumulates additional learning activity information as a learner enters and leaves the situation-based learning to provide an adapted learning situation when the learner starts his/her learning next time. In our system, the process of the training behavior utilizes a synchronous mode to support real-time interactions not only with simple text forms but also with audio, video, and chatting resources. The primary aim of the synchronous mode of the system is to provide learners with an interactive learning environment similar to classroom experience. The development of communication environment using such media as graphics, image, audio, and video has become a main stream for interactive learning. This kind of communication technology allows the learners to engage in training problems individually, and in cooperation with the tutor, and/or other learners in the system. Within this synchronous learning mode, learners will be able to ask questions via an audio and video channel.

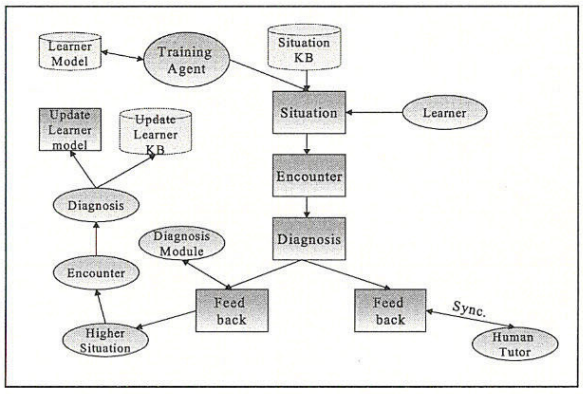


Fig. 5. Process of the training behavior

5. Conclusions

The purpose of this paper is to illustrate an intelligent adaptive system that utilizes an agent technology for tutoring and training support. Among the many features of the proposed system, one unique approach of our proposed system is adopting a learning environment based on agent architecture, which provides individualized support for problem solving. To realize this kind of approach, the proposed system uses a Learner Model to dynamically diagnose learner action. In the system each agent is extended by Communication Agent, which provides support for managing protocols among agents. Agents have the ability to communicate with other agents, reason and make decisions. In the proposed system we presented two main agents employing problem-based and situation-based learning architecture. The Tutoring Agent communicates with other agents and their interactions

determine the behavior of the whole system. Tutoring Agent is launched to collectively diagnose learner's performance. During the learner's interactions with the system feedbacks on individual learning promote the learner's learning progress. The system has ability to track learner's progress and provide the needed learning content required for the individual learner. In the Training Agent, a situation and simulation assisted learning based on VR is proposed. To help learners properly understand the situations and the simulation, we utilize the experiential VR training method. The Training Agent is believed to improve the speed of displaying interaction of 3-D operation model and establish an agent assisted learning simulation. The system supports synchronous and asynchronous cooperation among learners, cooperation being achieved either between the learner and the tutor or inside a group of learners interacting with or without the tutor.

An advantage of the proposed system over other system is its accurate diagnosis feature using the problem-solving strategy. As we improve this existing system, research has branched out into Learner Modeling and intelligent agents to support learning in a more intelligently adaptive environment. Also, in order to emphasize various aspects of the experiential learning, the VR environment is used. As a matter of course, the present paper was limited in intelligent scope. To reach a fuller solving of the problem, we need to look more closely at this. Thus, further studies on different deep research assessments are needed. We look out possible applications of the research are intelligent mentoring, adaptive collaboration learning. Also we believe development of various agents provide a stepping-stone for developing an account of intelligent learning. In conclusion, while the proposed system is believed to satisfy learners with a more learner oriented learning interface and result in practical learning outcomes by employing learning application approach throughout the learning process, we expect more experiment and evaluation of both the system and the learner satisfaction to improve the functional quality of the system.

References

[1] S. Ritter, Artificial intelligence in education (IOS Press, 1997).

[2] K. Cat & H. Peter, Designing agents for feedback using the documents produced in learning. International Journal on E-Learning, 4(1), 2005, 21-38.

[3] Lora, A. & K. Piet, Intelligent agents for educational computer-aided systems. International Journal of Interactive Learning Research, 10(3/4), 1999, 235-242.

[4] A. Mitrovic & S. Ohlsson, Evaluation of constraint-based tutor for a database language. International Journal on AIED, 10(3-4), 1999, 238-256.

[5] L. Teresita & S. Raymund, Learner agents as student modeling: Design and analysis, IEEE International Conf. On Advanced Learning Technologies, 2003.

[6] C. Henda & J. Mohamed, PERSO: Towards an adaptive e-Learning System. International Journal of Interactive Learning Research, 15(4), 2004, 433-447.

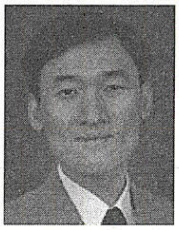
[7] W. Carine, B. Loris, P. Sylvie & B. Nicolas, The Baghera project: A multi-agent architecture for human learning, available at http://julita.usask.ca/Madmuc/Baghera.rtf, 2001.

[8] A. Martens, Support cognitive processes in intelligent tutoring systems, Proc. Of the International Conf. on Cognitive Modeling, Bamberg, Germany, 2003.

Authors

Joung-souk Sung

Received a Ph D. degree in computer engineering from Sungkyunkwan University, Korea, 1999. In 1998 she joined the faculty of BaekSeok College, Korea where she is currently a professor in Department of Computer Information. Her research interests include Multimedia System, Distance Education & e-Learning LMS System, LCMS, Intelligent Agent System, Digital Contents Authoring & multimedia source production, HRD & Continuing Education, Human Computer Interface.



Doo-hun Lim

Received a Ph D. degree in Education from University of Illinois, USA, 1998. In 2000 he joined the faculty of University of Tennessee, USA where he is currently a professor in Human Resource Development. His research interests include Learning Object Architecture, Learning Content Development and Authoring System, LCMS, Blended Solutions for Learning and Performance, Evaluation of Learning, Motivational Strategies Promoting Online Learning, Performance Improvement Technologies.