Building a General Purpose Pedagogical Agent in a Web-Based Multimedia Clinical Simulation System for Medical Education

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Abstract—In medical education, pedagogical agents are widely used by computer learning systems to simulate tutors and/or mimic tutoring interactions, as well as offering just-in-time and adaptive feedback. Although the theoretical aspect of the pedagogical agents has been well-documented in literature, relatively fewer efforts have been made on how a pedagogical agent should be implemented in a real multimedia computerized simulation learning environment. In this paper, we propose a general purpose pedagogical agent architecture and implement it in the multimedia medical simulation Web-based learning system called Health Information Network Teaching System (HINTS) to further facilitate students' learning and thereby make the HINTS a more helpful educational tool. Our focus is the design of the general purpose pedagogical architecture and its implementation in a multimedia computerized simulation learning environment. A preliminary students' performance evaluation result is also reported. We analyzed how to evaluate the students' performance and how the hints were given by the pedagogical agent. The system has been installed in the National Cheng Kung University Medical Center, Tainan, Taiwan for trial purposes. Some experiments have been conducted and the results have shown that the pedagogical agent indeed help the students in their learning process.

Index terms—e-Learning for medical education, pedagogical agent, computer-assisted learning, virtual peers, human-computer interaction, learning companions.

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1 INTRODUCTION

THE problem-based learning (PBL) model [1], [2], [3] has its roots in the apprenticeship or learning-by-doing method. It emphasizes a "real-world" approach to learning: a student-centered process that is both constructive and collaborative and has been widely used in medical education [4], [5]. In practice, instructors must not only be experts in their specific knowledge domain, but also be specially trained as guides to entertain, motivate, and provide hints to their students. Therefore, although PBL is a very effective learning method in some cases, it is usually a very labor-intensive and time-consuming process for the instructors. Since the World Wide Web and multimedia technology have attracted a great deal of attention as a vehicle for delivering e-Learning, some medical schools

and centers have incorporated multimedia computerized PBL into their clinical training curriculum to make PBL clinical education more efficient [7], [8]. The theoretical aspect of the multimedia computerized PBL has been studied extensively in [9], [10] which described it as online authentic learning. Therefore, we will not repeat the details of the theoretical foundation and concepts. However, current multimedia computerized PBL systems still have some drawbacks that may impair the efficiency of the students' learning. For instance, they do not really emulate the traditional PBL clinical education where the teachers can not only entertain, motivate, and provide hints for the students but also diagnose the students' misconceptions and resolve them. Therefore, although multimedia computerized PBL clinical education is more efficient than traditional methods in terms of the labor involved, it may be less effective. However, an agent-assisted, computer-based architecture may be employed as a promising medium for implementing a multimedia computerized PBL environment [11], [12], [13].

We have implemented an interactive multimedia computerized PBL clinical education system called Health Information Network Teaching System (HINTS) [14]. In the HINTS system, students: 1) are puzzled and challenged by the patient's problems; 2) try to interactively get more information needed from the system, such as questioning the patients and ordering various laboratory tests, as well as getting the associated multimedia information from the system, such as Computed Tomography (CT) images and the sound of the patient's heart beats; and 3) work on their ways in an attempt to diagnose and cure the patient's

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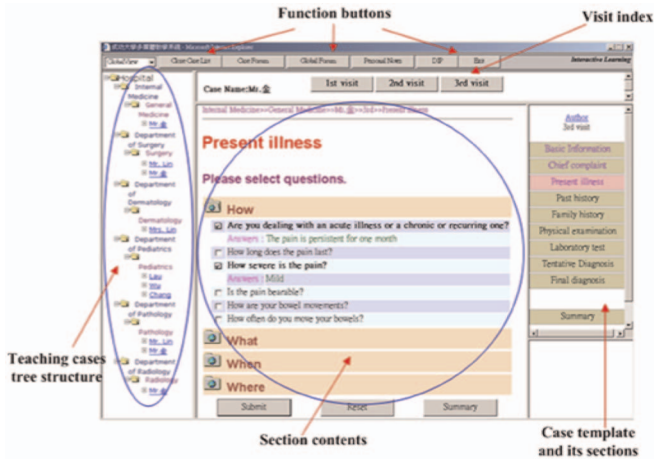
Fig. 1. The layout of the main HINTS windows.

problem. In other words, the HINTS can simulate the step-by-step scenario of a real clinical case in a clinical setting without using 3D virtual reality techniques—the 3D visual effects. The details will be described later on. In other words, the HINTS simulates the clinical setting and enables students to work on the virtual patient to practice their diagnostic thinking processes and skills.

Although the theoretical aspect of the pedagogical agents has been well-documented in literature [15], [16], [17], [18], less efforts have been made on how a pedagogical agent should be implemented in a real computerized simulation learning environment. We propose and implement here a general purpose pedagogical agent architecture that inhabits the HINTS to further facilitate the students' learning and make the HINTS more effective and efficient for learning. In the domain of learning, "effectiveness" describes the learning outcomes (better grades) whereas "efficiency" is always associated with time (studying faster) [6]. Although our focus is the design of the pedagogical architecture and its implementation, a preliminary students' performance evaluation result is reported. The result shows that the agent can make the learning more efficient. However, a more in-depth evaluation of the effectiveness of the system is still needed in the future. We will follow the same definitions in this paper. In Section 2, we present how the HINTS really works in practice and briefly describes the theoretical backgrounds of the pedagogical agent adopted by HINTS. In Section 3, since the pedagogical agent has to evaluate the student's performance in order to decide how to provide timely hints to the students, we will discuss how the student performance is evaluated in the HINTS. We will also describe how the pedagogical agent works from the students' point of view to facilitate their learning. In Section 4, the architecture of the pedagogical agent and some implementation issues are discussed. In Section 5, we will report the results of our experiments with the system. Finally, we will offer our conclusions in the Section 6.

2 BACKGROUND

2.1 Description of HINTS

For explanation purposes, we will briefly give an example of how the HINTS works first. The main window of HINTS is shown in Fig. 1. The left panel of the window is the
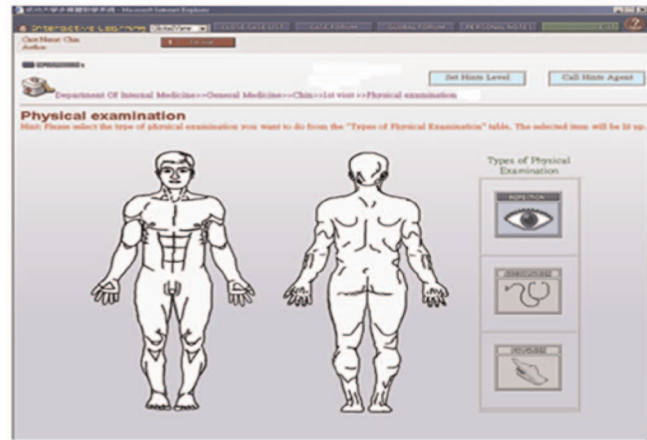
(a)

(b)

Fig. 2. The presentation of the Physical examination and Laboratory test. (a) The section on Physical examination. (b) The section on Laboratory tests.

display of the teaching cases organized as a tree structure. The right panel of the window is the display of the sections of a given teaching case. The student is supposed to select a case first, then select one of the sections for browsing the selected case. The contents of the corresponding section will be displayed at the center portion of the window. The HINTS is basically a PBL system in which the student is challenged by the initial status of a patient and works his/her way toward a correct final diagnosis (by browsing through several sections) followed by the patient management until the patient is completely cured. In other words, HINTS is a simulation system that allows the users to diagnose and cure the virtual patient in the system. In the HINTS, the student is first challenged by the patient's chief complaints and reads the patient's basic information section where the patient's height, weight, age, and so on are described. Then, in the present illness section, the system will present to the student many questions to ask the patient. The student is supposed to select which questions are critical to ask in order to reach a correct diagnosis for this particular case and the corresponding answer to the selected question will be shown by the system. In the Physical Examination (PE) section, the system presents a patient's figure as shown in Fig. 2a. The student is supposed

to first select one of the PE types: inspection, palpation, and auscultation followed by clicking on the part of the human body where the selected PE should be carried out. The system will respond with the associated multimedia information, such as the heart beat sound for the auscultation of a certain point on the patient's chest, and the picture of the skin for the inspection of a certain part of the patient's body. In the laboratory section, the student is supposed to enter a hypothesis—a disease name followed by clicking on various test items as shown in Fig. 2b to test against the hypothesis. The system will display the associated test results, such as CT images or ultrasound images. The same process can be repeated over and over again. In the course of this diagnosis procedure, the student can go back and forth among these sections until he or she gets enough information and feels comfortable to give a correct final diagnosis followed by the patient management section.

The HINTS is a multimedia simulation system that allows students to deal with the virtual patient in the system to emulate the situation when dealing with a real clinical case. However, whenever the students have difficulty dealing with the patient's problem, they are unable to get any guidance, encouragement, or other reference information from the system. In other words, the students are completely on their own when browsing a teaching case in HINTS.

2.2 The Theory the Pedagogical Agent Relies on and Related Literature Survey

From a theoretical point of view, between the potential competence level and the actual competence level a student has, there exists a zone of proximal development proposed by L.S. Vygotsky [19] to characterize scaffolding. This zone can be regarded as an area where scaffolds are needed to promote learning [20]. Scaffolds to be provided include vertical and horizontal levels as a temporary support in the zone of proximal development [21], [22]. Depending on the learning performance, the instructor gradually gives more control of the learning activities to the student. Scaffolding also encourages the use of language or discourse to promote reflection and higher order thinking [4]. We make use of an animated pedagogical agent [23], [24] to implement the scaffolding support in the HINTS learning environment.

There exists a wide spectrum of pedagogical agents according to their complexity and sophistication [25], [26]. For instance, there is "Adele" [10], [27], which makes use of rules to highlight specific aspects of a clinical case, suggests correct procedures for the students, provides hints and rationales for particular actions, refers to relevant background material, and provides a contextual assessment. Although Adele and similar systems make use of advanced artificial intelligence technology and are very sophisticated [28], [29], they are very "domain and application" specific. In other words, they may not be directly applicable to any other systems without modification. Their development also involves enormous input from the domain experts and the programmers. At the other extreme of the spectrum of pedagogical agents, a pedagogical agent may be much less sophisticated but more general and easier to develop. This paper is intended to develop such a general purpose

pedagogical agent—applicable to any multimedia simulation learning environment—that will not only assist students to learn, but also can be easily implemented.

Although the theoretical aspect of the pedagogical agents has been well-documented in literature, relatively fewer efforts have been made on how a pedagogical agent should be implemented in a real multimedia computerized PBL simulation learning environment. This paper is an attempt to develop a pedagogical agent to deal with more general problems that students in a PBL simulation learning environment may encounter. We will focus on the implementation issues rather than the theoretical aspect of the pedagogical agent. The pedagogical agent has a life-like persona [30]—the Merlin developed by Microsoft [31] (Microsoft Corporation, 1998 as part of the MS Agent package)—that is able to interact with students on an ongoing basis. The Merlin can speak, via a text-to-speech engine or recorded audio. The Merlin enables the students to feel that HINTS is easy to work with and increases student motivation and attention. Since the Merlin is used as the representative of this computer-assisted system for instructions we proposed here, we use "the pedagogical agent" to refer to our system instead of "a computer-assisted system for instructions" or "a multimedia hint system."

Furthermore, since our medical center is committed to globalizing our education system, another reason to use the Merlin as the representative of the system is to have the Merlin to show up and speak to the learners in English using the Microsoft's text-to-speech mechanism such that the learners can have more listening comprehension practices as a by-product of our system. In other words, using the Merlin is not a "must" for our system; perhaps a pure text-based dialog system without Merlin works just as fine, or even better, in other environments.

2.3 The Basic System Architecture Block Diagram

Our HINTS PBL teaching case system is essentially a multimedia Computer-Aided Instruction (CAI) system. Generally speaking, a CAI system is composed of three major models: a knowledge model, a student model, and a tutor model [32]. We further describe the details of these models here as follows.

1. *Knowledge model*: This is a database that contains knowledge on specific topics which an expert in that particular domain would reasonably be expected to possess. In our system, the knowledge model contains data related to many different clinical cases which are to be learned.
2. *Student model*: This model provides a mechanism for assessing the state of the student's current knowledge of the information held within the knowledge base.
3. *Tutor model*: This model tries to play the role of a human tutor and is responsible for managing the overall learning environment.

The pedagogical agent is put into the picture of the CAI system as shown in Fig. 3, in addition to these three models for facilitating the learning environment. We will further elaborate the system architecture in Section 4.
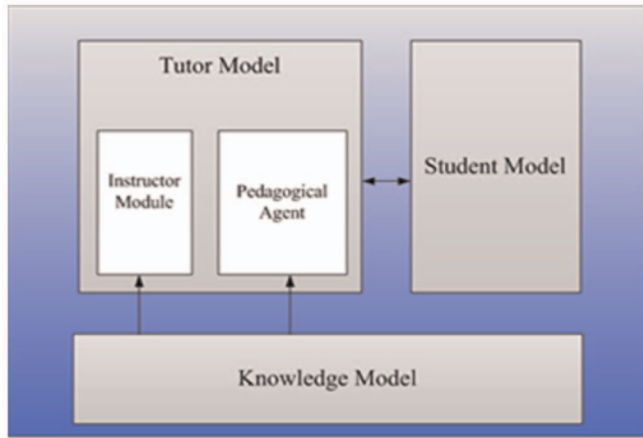
Fig. 3. The pedagogical agent in the CAI system.

3 THE FUNCTIONALITY OF THE PEDAGOGICAL AGENT

Since the agent should be able to provide appropriate hints to the students at the appropriate time, it must analyze the student's performance when practicing a teaching case, build a database of past activities, and provide students with hints to answer the questions. As described previously, rather than giving students implicit hints that may require specific domain knowledge channeled through AI technology, the system provides students with explicit hints to enable them to answer the questions directly. Although these kinds of hints are less attractive and less inspiring from the student's point of view, they are easier to implement and apply to all sorts of teaching cases since specific domain knowledge is not required.

3.1 The Performance Evaluation

Since the pedagogical agent has to evaluate the student's performance in order to decide what to do, the way the student performance is evaluated in the HINTS system is discussed here.

A student's overall performance in a teaching case is the weighted sum of the performances of all the sections in the case. In general, each section has many items for the students to select and there are some "suggested items" that are specified by the domain expert and are supposed to be selected by the students. The reason the term "suggested items" is used as opposed to the "correct items" is that for a given case in a clinical setting, there are usually several different approaches for a clinician to diagnose a patient's disease and it is virtually impossible to clearly define what is correct and what is not correct. However, for the sake of the argument, one can think of the suggested items as the correct items that the experts suggest the students to select. In the HINTS, there are two statistics derived from the students' answers that are significant and should be shown to the instructors for their reference: one is the "suggested hit rate"; the other is the "selected hit rate," and are defined as follows: 1) The "suggested hit rate" is the percentage of suggested items selected by the student. This indicates whether the student has indeed learned what he/she is supposed to. In other words, it reveals how "effectively" all the items are selected by the student. For instance, in the laboratory test section, there are more than 4,000 items the

student can select for the diagnosis. There may be only 10 suggested items. If five items in these 10 suggested items are selected by the student, the student's suggested hit rate is 50 percent. 2) The "selected hit rate" is the percentage of suggested items out of all the items selected by the student. This reveals how "efficiently" the items are selected by the student. For instance, suppose that there are only 10 suggested items in the laboratory test section of a teaching case and all of them are selected by a student. The student's suggested hit rate is 100 percent. However, in total, the student selected 100 laboratory items (which included the 10 suggested items) in the course of diagnosis. His/Her selected hit rate is only 10 percent. Although the student eventually got the right diagnosis, this may imply that he/she does not efficiently make use of his/her knowledge. In other words, the student, in fact, did not do a good job in this case although he/she did get whatever needs to be selected and the correct final diagnosis of the case. Therefore, his/her performance should not be the same as one who selected only 15 items and also got all the 10 suggested items. Generally speaking, both suggested and selected hit rates are useful indications as to whether the students have really mastered what they are supposed to learn. Therefore, in our implementation, these two factors constitute the overall performance of each section with the default weights 0.6 and 0.4 for the suggested and selected hit rates, respectively, for the laboratory section, and 0.8 and 0.2 for the interrogation inquiry and physical examination sections. This is because for the interrogation inquiry and physical examination sections, the extra questions asked of the patient and physical examinations do not really cost anything other than the physician's time while the extra laboratory examinations do cost money or even the patient's health. Therefore, the "selected hit rate" should be less important and be counted for less.

3.2 Horizontal Scaffolding

As stated previously, the scaffolds to be provided include vertical and horizontal levels. Since a teaching case in the HINTS is partitioned into several sections, the horizontal scaffold can be built up on a section-to-section basis. In other words, in each section, the system tries to build up the scaffold for each section independent of other sections (without considering how the scaffolds in other sections are done). As opposed to the horizontal scaffolding, the vertical scaffolding, which will be discussed in the next section in detail, considers how to build up the scaffolds to support students' learning over several sections.

Whenever the student finishes up a section, the agent will check the student's answers against the correct ones. Whatever is missed by the student will be used as hints for the student. Since each section in the HINTS is a multiple-selection type of question, it is very easy for the system to provide these hints to the student.

However, in practice, students may want to try out the teaching case on their own to some extent (without any hints). For instance, the student may say: "Please leave me alone unless my performance is less than 60 percent (in terms of the performance described previously)." In other words, the system should enable the students to set the level for horizontal scaffolding hints so that he/she can adjust it based on his/her own subjective confidence

Fig. 4. The pedagogical agent interacts with the student for the hints. (a) Ask the student whether he/she would like to get some hints. (b) Reveal hints. (c) The resources of the item are displayed after the hyperlink "View" is clicked in (b). (d) The rationale of the item is displayed after the hyperlink "The rationale of this item provided by the author" in (c) is clicked.

instead of the objective observation of his/her performance by the system. This arrangement will make the system more adaptive to each individual and become more interesting and challenging for students to use [33], [34].

Therefore, at the beginning of a teaching case, the hints level is set to a certain level such as 60 percent. Since the student's performance is evaluated in such a manner as described above, roughly speaking this means that if the student does not select 40 percent of the correct answers, the remaining 60 percent of the correct answers may be revealed to the student at the end of each section. If the hints level is set to zero, the agent will never show up. If the hints level is set to 100 percent, the agent will always show up and provide hints. The agent will tell the student what percentage of the correct answers have been selected by the student—say "30 percent"—and ask the student whether or not they wish to see the hints. There are two possible results:

1. The student may be surprised at the 30 percent of his/her correct answers in this example, realizing that he/she is not doing a good job in the current section, and would like to go back to this section to re-examine the questions more carefully without further hints. In this case, the student would select "No" and go back to the section to reselect more items. In our experiments, surprisingly, the students thought that it was a very useful aid for them to

practice the case. It is particularly useful for a novice since it gives the student a rough feeling about how well he/she is doing. When the student finishes up the second trial for the section, the system will re-evaluate his/her performance again and the same process will repeat itself.

2. If the student selects "Yes," then the agent will ask the student whether or not he/she wants to get one correct answer at a time or get all of the correct answers at the same time, as shown in Figs. 4a and 4b, respectively. In the former case, the student can click the "view one more item at a time" button and one of the answer items will be shown first so that he/she can think about why the item should be selected first before more details about the item are revealed. For instance, for the example shown in Fig. 4b, the item RBC morphology is shown. When the student clicks on "View" in the Report column, through the hyperlink, the student can read more information pertaining to the item, such as why this item should be selected (the rationale of this item provided by the author) and what RBC morphology is about as shown in Fig. 4c. If the hyperlink "The rationale of this item provided by the author" in Fig. 4c is clicked, the rationale of the item in Fig. 4d is displayed. This arrangement will allow the

student to think about how to approach the correct answer incrementally and give the student more opportunities to think about the problems instead of just reading the answer directly.

At this point, the student is strongly encouraged to read the answers one at a time so that he/she has a chance to think about what the answers imply. Hopefully, after a few answers are shown, the student can realize what is going on, then shut down the agent, and go back to the section to continue to work on the case on his/her own.

3.3   Vertical Scaffolding

As for the vertical scaffolding, it is used to help the student in terms of his/her overall performance instead of that of each individual section (done by the horizontal scaffolding). In the context of the multimedia computerized PBL, if the student does not really catch onto the important point at the beginning of a case study, he/she may go astray and go toward a completely wrong direction. In such a situation, the teaching case may become a "big jungle," and the student is simply making random guesses and struggling to get out of it instead of learning anything meaningful, and getting very frustrated in the process.

In order to analyze this situation, we first define two different learning models in the context of PBL learning models: straight model and regression model. In the straight model, the system will allow the student to work his/her way toward a solution to the problem regardless of whether he/she is on the right track or not. This model is, in general, reasonable for a short exercise. However, it may not be suitable for a long learning task. For instance, if the student gives a wrong diagnosis, the rest of the patient management procedure might be detoured to a completely different clinical pathway which may be perfectly correct for the given diagnosis (which is wrong). In general, in the lengthy problem solving process of a PBL environment, a small error upfront may affect all subsequent results and result in a large problem at the end. In this case, it is difficult to evaluate how much knowledge the student does correctly understand. One way to fix this problem is to use the "regression" model.

In the regression model (within the context of the medical teaching case system), the whole diagnosis and treatment procedure of a teaching case that the system emulates is divided into several stages. The system will establish a checkpoint at the end of each stage. At each checkpoint, irrespective of whether the student is on the right track or not, the agent will always appear and ask the student whether or not he/she would like to see the summary of the current status of the case at that point in time. The summary outlines the situation and the status of the correct clinical pathway at that particular point in time. If the student selects "Yes," the system will show him/her the summary. In other words, the student will be informed of what he/she should know about the case at this particular point in time and, in effect, "restart" the case from this correct point on. This arrangement enables the system to correct the student's thinking process at the end of each stage of the clinical pathway. Therefore, this mode is more suitable for a novice.

In our implementation, we use the regression model since each case study in our system is a lengthy problem-based learning process. The regression model will make the learning more effective and prevent the students from getting frustrated. Every teaching case in the system was divided into three stages, each of which consists of several sections of the case. They are: 1) the present illness stage includes basic patient information, chief complaints, and present illness sections. At the end of this stage, once the student has completed his/her patient interview, he/she is supposed to fully understand what the patient's current conditions are in order to make the rest of the learning procedure more meaningful. The HINTS system will summarize what the present illness is so that the student can conduct further examinations based on the patient's current situation. Otherwise, if the student does not fully understand the present illness, he/she may consider the case in a completely different direction and continue on the wrong track. 2) The diagnosis stage includes past history, family history, physical examination, laboratory test, and diagnosis sections. At the end of this stage, the student is supposed to have reached a correct diagnosis in order to make patient management in the following section more meaningful. Therefore, if the student does not get a correct diagnosis, the system will either provide him/her with the correct diagnosis or ask him/her to try again until he/she gets the correct one. This arrangement will make the next stage—the patient management, more meaningful in case that the student did not get the correct one. 3) The patient management stage. At the end of this stage, the system will give the student a summary of how he/she performed in each individual section as well as his/her overall performance, costs incurred to date, how much time was spent, and so on.

However, as the student becomes more sophisticated in the clinical pathway and can answer at least half of the questions correctly, the summary will make the case less challenging and less interesting. Therefore, the pedagogical strategy is to start with the regression model containing many stages, then progressively reduce the number of stages in the regression model, and eventually switch to the straight model.

Furthermore, at each checkpoint, the agent can also evaluate how well the student has done in the associated stage by taking the average of the overall performance of all the sections in the stage. If the student's performance is outside the range of the scaffold level of $+/-15$ percentage points, the agent will suggest to the student that he/she should lower/raise the scaffold level to match his/her own performance.

4   THE ARCHITECTURE AND THE PEDAGOGY STRATEGY OF THE HINTS SYSTEM

As stated in the background section, the basic architecture block diagram and the pedagogy strategy of the agent are shown in Fig. 5. The horizontal and vertical scaffolding engines described in the previous section and the horizontal scaffolding database form the pedagogy strategy of the agent in the system. The agent architecture is carefully designed in such a way that it is independent of the HINTS so that HINTS can run with or without the agent. This is an important feature, as it also allows HINTS to be used for testing purposes (without the pedagogical agent). In other words,
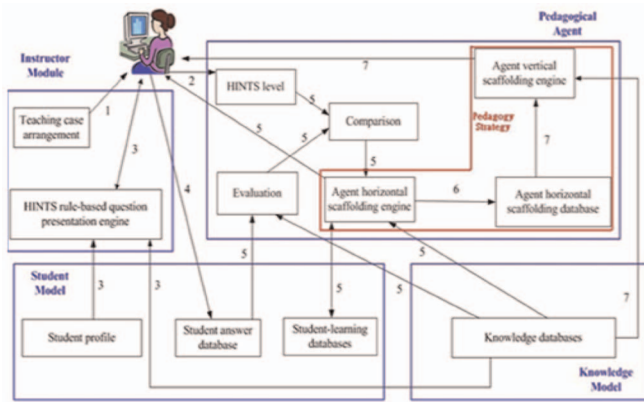
Fig. 5. The HINTS architecture.

the agent is simply an additional educational companion that may or may not show up when HINTS is used.

The system works in the following fashion:

1. The instructor module arranges the teaching cases to be learned.
2. The student can set the hints level or simply ignore it (in this case, the default value is used).
3. Based on the teaching case selected by the student, the instructor module references the student profile database and the knowledge model database, then uses a rule-based engine to present the teaching case to the student in the PBL fashion described earlier.
4. The student's answers are stored in a log database.
5. At the end of each section, the agent evaluates the student's answers against the suggested items in the knowledge model, compares the evaluation result with the hints level, and offers hints to the student accordingly through the horizontal scaffolding engine, storing them in the student learning database for future usage.
6. The horizontal scaffolding engine also records the results in the horizontal scaffolding database.
7. At each checkpoint, the vertical scaffolding engine references the horizontal scaffolding database and the knowledge model, and provides the vertical scaffolding to the student. Although the architecture of the agent is not simple, there is no huge amount of computation involved. As a result, the students do not really feel any delay while interacting with the system with the existence of the pedagogical agent.

5 INITIAL FIELD TESTS

HINTS has been up and running in the medical center of National Cheng Kung University for three years. Currently, there are 50 teaching cases in the system for the clinical practice training of the medical school students. The system was implemented on Microsoft Internet Information Server version 6.0 (IIS), and SQL database technologies. Students can simply use the World Wide Web (WWW) browser to login to the HINTS and browse the teaching cases at the computer center in the medical school or at home, if a wide-bandwidth Internet connection is available. Before the pedagogical agent was installed in the system, more than

200 medical school students from the fifth to seventh grades (equivalent to first to third grade students in a medical school in the American medical education system) have had experience in using the system.

Since the main purpose of this study is to investigate how a pedagogical agent should be implemented in a real computerized simulation learning environment, such as the HINTS, we need to find out whether the designed pedagogical agent is really effective especially for the training of the thinking process. Therefore, we hypothesize that the pedagogical agent can improve the efficiency of the students' learning. The following is the description of our field test method and its results.

5.1 Participants of the Experiments

The participants of the experiments were 80 students from the fifth and sixth grades in our medical school. These students have been using the HINTS for many times over several months and have had no problems in using the HINTS [35]. They were randomly partitioned into the control group A and the experimental group B with 40 students in each group. In the HINTS system, the system administrator could turn on or off the pedagogical agent. Group A used the system without the agent while group B used it with the agent. The students in both groups did not know that only half of the students would receive additional hints.

5.2 Experimental Design

There are six teaching cases used in the experiments: two simple ones, two mediocre ones, and two difficult ones. The students browsed through these cases sequentially. We measured how many times the students had tried before they got at least 60 percent of the correct answers. The focus of this experiment is to see whether the hints provided by the pedagogical agent can improve the efficiency of the students' learning. Since this experiment includes only two groups: the control group and experimental group, we made use of the t-test for the computation of the result of the experiment that is shown in Section 5.4.1.

Furthermore, right after the students of group B finished their browsing of the six teaching cases, some survey data were collected by asking them to fill in an online questionnaire. The questions in the questionnaire are designed simply to see whether our design and implementation of the pedagogical agent is effective or not. In order to obtain a reliable survey result, expert validity was adopted in this study. The questions in the questionnaire were reviewed, revised, and eventually approved by six experts including three medical education experts, one statistics expert, and two information science experts.

5.3 Procedures

In order to ensure the correctness of the evaluation of the agent system, we have the following procedure. Prior to the evaluation, we demonstrated the HINTS operation including the mechanism of the agent to all the students and made sure the students could use HINTS without difficulty. At the beginning (the first classroom lecture for a case), the instructor gave the students some background knowledge about the particular case in the classroom. Then, the students browsed through the case including reading through the basic information and chief complaint sections in HINTS, specifying which part of the patient's

TABLE 1
The Results of the t-Test

Difficulty level of the Cases	group	Number of students in the group	Average times of the students' trials	Standard deviation	P-value
Difficult	A	40	10.1	1.19	0.0009
	B	40	5.15	0.73	
Mediocre	A	40	8.37	1.21	0.0007
	B	40	4.95	1.29	
Simple	A	40	6.17	1.5	0.001
	B	40	4.02	1.2	

TABLE 2
Summary of Results from the Student
Responses to a Series of Questions

Questions (n=40)	Mean value	Standard deviation
Have you ever used the HINTS before?	4.7	0.45
Are you familiar with the operations of the HINTS?	4.625	0.48
Do you know that there is an agent in the HINTS?	4.675	0.46
Do you fully understand the purpose of the hints level setting of the agent in the HINTS?	4.675	0.46
Does the agent in the HINTS help your thinking process for your learning?	4.575	0.49
Does the agent in the HINTS interfere with your learning?	1.45	0.48
Do you think that the agent in the HINTS help your learning?	4.7	0.45
Does the agent in the HINTS make your learning more interesting?	4.55	0.49
Does the agent help you avoid some mistakes or misconceptions?	4.575	0.49
Do you agree that the agent can improve the effectiveness of your learning?	4.45	0.49
Do you agree that the agent can improve the efficiency of your learning?	4.525	0.49

body should be examined, what questions should be asked, and what laboratory tests should be ordered to get more information and insight into the patient's status from HINTS, and finally gave their final diagnoses for the exercise. All the students' answers were logged by the system for further analysis. Furthermore, as described before, some survey data were collected by asking them to fill in an online questionnaire right after the students of the groups finished browsing the six teaching cases.

In the second classroom lecture, the instructor and students discussed the results computed by HINTS and their experience with the teaching case.

5.4 Results

5.4.1 Analysis of the t-Test

As described before, we measured how many times the students had tried before they got at least the 60 percent of the correct answers. The 60 percent score in group B does not include those answers provided by the agent. By using an Independent Samples t-test procedure, where $P < 0.05$ is considered to be significant, the average, standard deviation, and P-value are computed by the software package SPSS 12.0 and are listed in Table 1. In Table 1, it can be found that there are significant differences between groups A and B in all the cases $(P < 0.05)$. Apparently, the pedagogical agent plays an important role in their learning activities.

5.4.2 Analysis of Questionnaire

Table 2 uses a five-point Likert Scale and summarizes the students' responses to a series of questions posed by the current researchers. The students have also made a variety of comments after using the various teaching cases in the system. The principal results of this study may be summarized as follows (some of the results are provided by the instructors):

1. As expected, the students all felt that the teaching cases with the pedagogical agent were much more helpful than those without the agent, especially for their thinking process. The results of the t-test also demonstrated the significance of the pedagogical agent.
2. All the students agreed that the system significantly improves their skills in dealing with actual clinical cases as shown in Table 2. The standard deviation values are very small. This implies that there is a consensus regarding the students' responses to the agent. We have also interviewed the students who have experiences with the HINTS with and without the pedagogical agent. They expressed that without the agent, when they do not have any idea on how to work on a case and they do not get any hints from the system, they simply do not know what to do other than making random guesses. In other words, they are completely on their own. With the agent, they can get some hints from the system. Furthermore, they can control how many hints they want to get from the agent. For instance, for any given clinical case, there are more than 2,600 possible laboratory test items for them to select. When they call on the agent, the agent can tell them which items should be selected little by little under their control. The hints do provide some clues and thinking directions for them to think about the case. Of course, sometimes with the hints, they are still confused. In any case, they are certainly better off with the agent.

3. The instructors feel that although the agent does not handle the students' problems intelligently in the sense that it cannot answer individual or specific problems, it does save the instructors a lot of time in working with the students throughout the teaching cases. They believe that the agent can serve students as a teaching assistant in their learning process.

4. From the system logs of the students' learning, the average times the students in groups A and B spent on a case are 51 and 37 minutes, respectively. In the student interviews, the students had expressed that they would like to be able to spend about 40 minutes on average on a case. Apparently, the agent indeed can make the learning more efficient and enable students to finish a case within 40 minutes.

6 CONCLUSIONS

In this paper, we describe how our multimedia pedagogical agent was designed and implemented in the simulation of the medical teaching case learning environment, such as HINTS. Although our focus is the design of the pedagogical architecture and its implementation, a preliminary students' performance evaluation result is reported. A more in-depth evaluation of the effectiveness of the system is still needed in the future. The system has been deployed and tested by the students. Based on our experiences, our conclusions are:

1. Although the agent does not really intelligently detect a student's misconceptions or provide them with customized hints, it can at least save the human instructors some time and trouble going through a teaching case with the students and providing constant guidance to the students.

2. Although a human instructor can certainly do a better job than the agent in terms of tutoring, the presence of a human instructor may put the students under some pressure. Using the agent, the students feel they can work through the teaching cases in a more relaxed and stress-free environment. In particular, the agent is indeed extremely useful for novices. This is because although they have enough basic medical knowledge for the clinical cases, they do not have enough experience in applying their knowledge to the cases. The agent is able to provide them with useful hints.

3. The teaching case needs to be developed by the domain experts without the development of the pedagogical agent in mind. However, the agent inhabiting the system can be easily developed without the "explicit involvement" of a domain expert since the agent simply reveals the items which need to be selected with their rationale and related resources little by little under the students' control. Of course, the hints information is originally provided by the domain experts as the answers to the problems under study instead of the hints to the students. In other words, the hints are provided by the domain experts implicitly and the system makes use of the agent mechanism to provide the hints information at the right time to the students when they need the hints.

4. Despite the preliminary success of the agent development, ultimately there is still a need to make the agent more intelligent in order to cope with the various and inevitable problems that students encounter during their learning process.

5. As discussed in Section 5.2, the pedagogical agent should not provide too many hints to the students without costing the students anything. Otherwise, the students will take the hints for granted without really thinking about how to solve the problems on their own and always try to rely on the hints instead of working with the system on their own.

6. Although the theoretical aspect of the pedagogical agents has been well-documented in literature, less efforts have been made on how a pedagogical agent should be implemented in a real computerized simulation learning environment. Here, we propose and implement a pedagogical agent architecture that inhabits the HINTS to further facilitate the students' learning and make the HINTS more efficient for learning. Our focus is the design of the pedagogical architecture and its implementation. A more in-depth evaluation of the effectiveness of the system is still needed in the future.

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