Mentor Agent: An Intelligent Virtual Teacher for Personalized Learning Environments

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Abstract: - A key issue in pedagogy is individualization, i.e., adapting the teaching to the needs of various learners. In many cases, however, current e-learning systems have so far focused most on porting existing courses with traditional teaching methods onto the web/virtual environments without any fine-tuning and adaptation to the learner needs, just making non-individualized teaching even more widely available. The intelligent agent technology has potential regarding the creation of more intelligent, personalized, adaptive and interactive e-learning applications, providing individualization and therefore enhancing the effects of learning. In this paper, an intelligent virtual teacher is presented to provide personalized content management, learner model, and adaptive instant interaction in virtual learning environment. Mentor provides information for the student, and rises to help whenever the student has lost the clues. The mind model of the mentor agent is proposed on top of the Dempster-Shafer Goal-Net architecture. User-awareness and context-awareness are both achieved by reasoning student activities and context evolvement. Proposed architecture is validated by applying on Singapore River City, an agent augmented virtual environment designed to engage and motivate students at the lower secondary level in Singapore. Extensive experiments illustrate the effectiveness of the proposed intelligent mentor where students have found the mentor agent as believable as a virtual teacher.

Key-Words: - Personalization, Agent augmented virtual environment, Goal-net agent modeling, Pedagogical Agent, Stock management, Dempster-Shafer Theory.

1 Introduction

Learning communities are now beginning to take many forms. There are the conventional classroom situations that still predominate, but increasingly new learning forms such as work based, just-in-time, and distance learning are emerging. The majority of current e-learning systems treat every user equally without any fine-tuning at the learning objects. An emerging issue in learning across the multi user virtual environment is a virtual training assistant that captures the subject matter and teaching expertise of experienced trainers provides a good motivating option. Intelligent animated pedagogical agents deliver such advice with a strong visual appeal. They inhabit interactive computer based learning environments and provide customized feedback to the students. They give the user an impression of being lifelike and believable as a virtual instructor or guide. Factors such as gaze, eye contact, body language, and emotional expression might be modeled and exploited for instructional purposes. Their lifelike and captivating presence motivates students to interact longer with educational software and consequently leads to have a significant improvement in the quality of learning results [1]. Pedagogical agents bring a fresh perspective to the problem of facilitating on-line learning, and address issues that previous intelligent tutoring work has largely ignored.

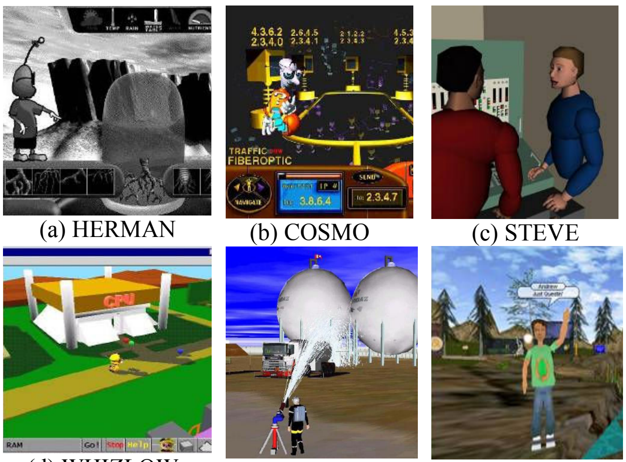
This research is to study the ways in which agent augmented virtual environments may aid the transfer of learning from classroom contexts into real world settings. In particular, this work is toward developing a believable virtual teacher who monitors and provides them with personalized guidance.

The paper is organized as follow: Section 2 presents the related works. Section 3 talks about the virtual environment. The proposed model is described in section 4. Section 5 is model evaluation and section 6 talks about possible future trends.

2 Previous efforts on pedagogical agents

During last decade, lots of empirical researches have been done into Pedagogical Agents and intelligent teachers. Herman the Bug [2], STEVE [3], COSMO [4], and WHIZLOW [5] are some of the animated pedagogical agents who inhabit a virtual environment provide hints and helps for the students. Herman the Bug [2] is the first known developed to inhabit virtual environments. After that, a 3D pedagogical agent called STEVE [3] was designed to interact with students in networked virtual environments for the aim of supporting the apprenticeship model of learning. STEVE demonstrates skills to students, answers questions, and gives advice if the students run into difficulties.

At the same time the IntelliMedia was working on COSMO [4], a 3D character that occupies the Internet Adviser for helping learners on Internet packet routing. The agent acts as an intelligent teacher and assists students to solve problems. COSMO has been used to investigate how to combine various agent behaviors in order to enhance deictic believability. WHIZLOW developed to inhabit the CPU City 3D learning environment. As a recent effort, Quest Atlantis [6] is a teaching project that uses a 3D multi-user environment to immerse children, ages 9-12, in educational tasks. Figure 1 shows some snapshots of these agents in their virtual environment.



(a) HERMAN (b) COSMO (c) STEVE
(d) WHIZLOW (e) MASCARET (f) QA

Fig. 1 Snapshots of pedagogical agents inhabit in virtual environments

Regarding architecture, three main architectures have been emerged for online generation of agent behavior [7]. (1) The *Behavior Sequencing Approach* is based on a behavior space, which is a library of predefined primitives (actions, Speech elements, etc). COSMO and Herman the Bug follow this architecture. (2) The second Architecture is the *Layered Generative Approach*, where animations are generated in real time. For on screen characters, there are distinct layers for problem solving, dialog model, physical focus and emotional appraisal. This is the architecture STEVE is based on, and it is especially suitable for immersive environments, but it requires a much higher rendering computation load. (3) Finally, the third architecture is *State Machine Compilation Approach* which composes behaviors out of primitives, but generates a state machine, so that the behavior of an agent can adapt at run time to student actions.

The current state of the art in pedagogical agents represents a promising step toward creating lifelike explanatory avatars for learning environments. However, significant challenges remains, including endowing lifelike avatars with models of emotion and providing them with much more sophisticated natural language generation capabilities to increase their flexibility and clarity of expression.

3 Singapore River City: Agent Augmented Virtual Learning Environment

The agent augmented virtual world used for prototype validation in this paper, Singapore River City (SRC), is developed to engage and motivate students at the lower secondary level in Singapore. SRC is a Singapore version of the existing US River City environment developed by Harvard University in which the synthetic characters in the new virtual environment are augmented with advanced agent technologies in order to investigate contextual, situational, social, and emotional dimensions of virtual experiences for learning. SRC is an interactive educational environment where students can access virtual architectures configured for learning, Interact with virtual residents as well as digital objects and represent themselves by graphical avatars. SRC proposes a graphical multi-user virtual environment with deep content and challenging activities where as the sample story, intelligent agents help students to investigate an unknown disease happened in the society. By using intelligent agents, different roles of society are presented from doctors, nurses, to several villagers who are vividly living in front of the students and provide guidance for them. Figure 2 is a snapshot of SRC environment.

Fig. 2 A snapshot of student view in SRC. *Mentor* and *Doctor* are interacting with the patience and student to provide Information about the environment.

4 Mentor Agent: Intelligent Virtual Teacher

A general agent called "Mentor Agent" is defined through the system which acts as a virtual teacher, controls the entire student's progress and activities through the system. "Mentor Agent" is a main coordinator through the system, who interacts with all the other agents, "Guide Agents", evaluates their efficiency and guides the student in all the locations as a permanent virtual mentor. Just after the time student leaves a location, "Mentor Agent" updates the activity and qualification of students according to the feedback reported by the communicated "Guide Agents" on that location. "Guide Agents" are other implemented agents through the society which currently includes Doctor, Nurse, and Sick Coolie whom students communicate with in each stage to find out the problem of the environment.

Based upon how effective the other agents have influenced the students, "Mentor Agent" considers some kind of rewards for those agents who communicate effectively with students. "Mentor Agent" determines how useful the "Guide Agent" has been acted facing with that particular student according to the feedback provided by the agent. Thereafter, next time when the students ask mentor where to go to investigate, the mentor will suggest the student those areas and those effective agents with a higher probability.

The proposed approach is discussed in three following sections: (1) "Learner modeling", which discusses about how to model the student in system (2) "Agent architecture" which talks about the architecture of "Mentor Agent" and (3) "Agent collaboration" focuses on the coordination and collaboration of "Mentor Agent" and other "Guide Agents".

4.1 Learner Modeling

One of the most popular standards for modeling learner profile is IMS Learner Information package. IMS consortium maintains an International Conformance Program to provide joint collaboration between communities interested in adapting the IMS specifications to their precise needs. IMS Learner Information package is based on a data model that describes characteristics of a learner.

The core structures of the IMS LIP are based upon: accessibilities, activities, affiliations, competencies, goals, identifications, interests, qualifications, certifications and licenses, relationship, security keys and transcripts.

Among all the IMS LIP items, the related items to preferences according to [8] are assumed to be "Activity", "Identification" and "Interests" while the system is basically built to serve as a platform for students as supplement learning environment rather than organization selection of new employees. Students could be modeled based on:

Identification = {Name, Id, Gender, Age}
Activity = {Visited Places, Collected Items,…}
Interests = {language, length of descriptions}
Qualification = {Absolutely Unfamiliar, Unfamiliar, Familiar, Very Familiar, Absolutely Familiar} (1)

where different variations of agent's scenarios are mapped directly based on the values of *"Interests"*. *"Identification"* includes information about student like name and student-id.

"Qualifications" is a fuzzy variable defined as the main parameter to record the student's performance through the system. It is mapped to familiarity and by that as a parameter of evaluation, we consider how familiar the student is with the problem and its possible solution through browsing the environment, fuzzy representation of *"Qualifications"* is shown in Figure 3. Finally, *"Activity"* is considered as the previous history of what the student has been done in the system.

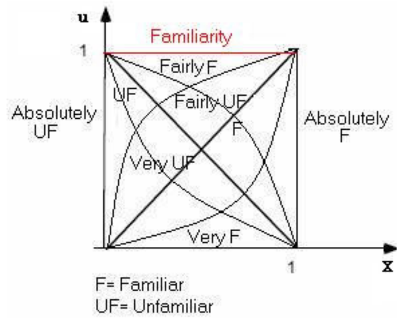


Fig. 3 Fuzzy representation of "Familiarity" considered as "Qualification" in IMS

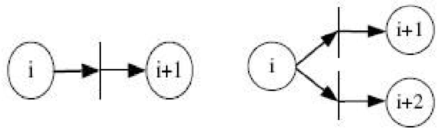
4.2 Agent Architecture

The "Mentor Agent" is following a Goal-net architecture. Goal-net is a goal-modeling tool for multi-agent systems proposed by Shen [9]. The Goal-net architecture is employed to design the plot for the "Mentor Agent".

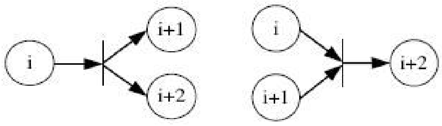
4.2.1 Goal oriented agent modeling

Goal orientation is an increasingly recognized paradigm for agent modeling and development. A goal of an agent can be described as a desired state that the agent intends to achieve. Goal-net [9] is proposed to model such complex goals of agents in an open distributed and dynamic changing environment. A Goal-net is hierarchically structured.

The root composite state at the highest level of the hierarchical structure represents the overall goal of the agent and the composite states in lower levels of the hierarchical structure represent sub-goals of the agent. An agent commences its goal pursuit from the root state; it then goes through the hierarchical structure to reach its final goal. Goal-net can represent four basic temporal relationships between states: sequence, concurrency, choice, and synchronization which are shown in Figure 4.



(a) Sequence (b)Concurrency



(c) Choice d) Synchronization

Fig. 4 Goal-net Transitions

In case of concurrency agent need to make decision about the next state to choose. Goal selection algorithm is on top of the Dempster-Shafer belief accumulation [10] which presents a model for agent's belief. Whenever agent reaches a concurrent state, agent's belief would be the decision making function for selecting the next goal in Goal Net.

4.2.2. Dempster-Shafer belief accumulation

The Dempster-Shafer theory is a mathematical theory of evidence based upon belief functions and plausible reasoning, which is used to combine evidences to calculate the probability of an event. The Dempster-Shafer theory offers a knowledge model about one or more hypothesis, enables to quantify such concepts as imprecise measurements or uncertainty, and agrees to allocate probability-like weights to a set of events in a way that allows statements of ignorance about likelihood of some of the events.

Dempster-Shafer theory [10] starts by assuming a *Universe of Discourse θ,* also called a *Frame of Discernment* which is a set of mutually exclusive alternatives. Elements of 2^{θ}, i.e. subsets of θ *are* the class of general propositions in the domain. A function m: $2^{\theta} \rightarrow [0,1]$ called a belief function assigns to each subset of θ a measure of our total belief in the proposition represented by the subset. There corresponds to each belief function one and only one basic probability assignment. Conversely, three corresponds to each basic probability assignment one and only one belief function.

They are related by the following two formulas:

$$\mathrm{m}(\phi) = 0 \text{ and } {}_{A \subseteq \theta} \sum m(A) = 1 \qquad (2)$$

$$Bel\,(\mathrm{A}) = {}_{B \subseteq A} \sum m(B), \text{ for all } A \subseteq \theta$$

Thus a belief function and a basic probability assignment convey exactly the same information. Evidence may be combined using Dempster-Shafer theory.

4.2.3. Dempster-Shafer goal selection

"Mentor Agent" is following a Goal-net architecture. Based on the goal net architecture, three different modes of activities are considered for "Mentor Agent" to follow (Figure 5). According to figure, the first option would be to act as an informative agent who goes to student providing some information about the environment and the current problem. The second state is acting like a question answering agent who provides a list of possible general questions to students to select and then shows them the proper answers. Finally, the third option would be the state where agent feels that student really doesn't need him and decides not to disturb the students.

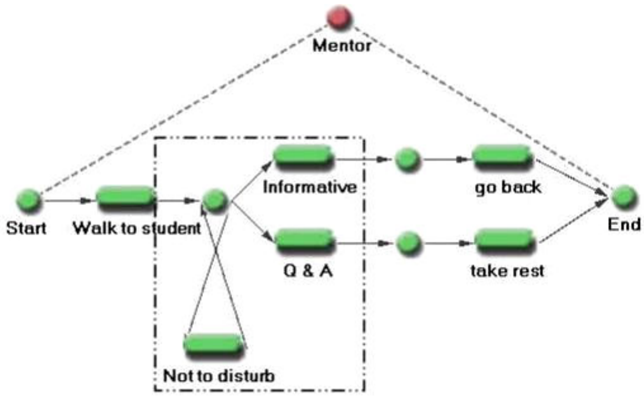


Fig. 5 Goal-Selection for "Mentor Agent"

In each state, agent needs to decide on one of the three possible states to follow. Decision making is based on the agent's belief on top of the Dempster-Shafer belief modeling. Frame of Discernment is defined based on *"Qualifications"* where mass function $m(Student_i)$, is the fuzzy amount of *"Qualification"* for that target students.

$$\forall\ A \subseteq \text{"Qualifications"} \qquad (3)$$

$$Belief\_Agent(Student_i) = \sum m_A(Student_i)$$

This means agent decides based on the performance of students. Whenever *Belief - Agent (Student)* is less than the predefined threshold, mentor runs toward the student and provides one of the answers listed in table 1. Otherwise, agent does not disturb the student. Agent mode would be "Informative" here. "Q & A" mode is the state where student herself wants to ask question by clicking on the "Mentor Agent".

4.2.4. Updating the learner model

$m(Student_i)$ as a measure of student progress through the system would be updated based on the different permuted states, locations, facing with agents and the results of taken exams. Student's performance is updated in two situations through the system. First one is whenever student leaves an especial location like Hospital, Market Place, and Chinese Medical Hall. Student's performance would be updated by mentor based on the feedback provided by communicated" Guide Agent":

$$\forall\ A \subseteq \text{“Qualifications”} \quad (4)$$

$$m_A(Student_i) = \alpha * m_A(Student_i) + \beta * A_A(Student_i) + \lambda * E_A(Student_i)$$

where $A_A(Student_i)$ is the "Guide Agent's" idea regarding the student's performance through the permutated stage, and $E_A(Student_i)$ is the way Environment parameter can be used for evaluating the student. For example the time each student has spent on each phase can be considered as a parameter of learning.

The second time to update Student's performance is after completing the entire phase. After each phase, there would be an overall exam taken by "Mentor Agent" as the virtual teacher or by the student's teacher and the results would be mapped to the student's performance through the below formula:

$$\forall\ A \subseteq \text{“Qualifications”} \quad (5)$$

$$m_A(Student_i) = \alpha * m_A(Student_i) + \rho * T_A(Student_i) + \lambda * E_A(Student_i)$$

where $T_A(Student_i)$ is the teacher's idea regarding the student's performance through the system or the results of the final exam taken by "Mentor Agent" after Completing a particular phase.

Right after completing a scene, based on how effective the other agents have influenced the students, "Mentor Agent" runs a reward/punishment algorithm through the society to increase the chance of the good "Guide Agent" for the next time to advice to the student. For each student, a particular value of effectiveness is defined through the system which its value is used as a metric to evaluate the effectiveness of interacted "Guide Agent". This value is updated based on the provided feedbacks by guide after interacting with students. Schematic of user interactions are illustrated in Figure 6.

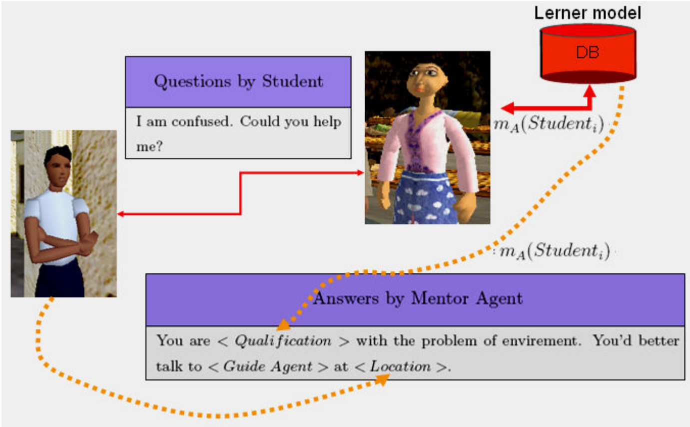


Fig. 6 Schematic of Interaction between Mentor and student

5 Prototype Validation

The main goal of the SRC is to teach students the skills necessary for scientific inquiries which are important in conducting investigations for a science fair project. Hence a topic of Dengue Education was chosen as the theme of the learning module. The environment has been gripped with a mysterious disease where students should browse the world and investigate on the disease. Mentor is the student's virtual teacher who monitors the student to help him whenever she feels the student needs help. Sample snapshots of mentor are brought up in Figure 7.

With the proposed social interaction model, pedagogical agents interact with students in a believable manner. The user-awareness and context-awareness are both achieved by reasoning student activities and context evolvement. Through collaboration in monitoring student's activities, Mentor collects the feedback from the Guides to provide personalized advices, and necessary instant messages. Mentor finds the best Guide that student can approach to get the best reply. Students found Mentor believable and quite entertaining.

According to the experiments, students generally expect pedagogical agents to be as believable as virtual mentors, entertaining, easy to communicate, helpful and diversified. Five prominent learner desires for pedagogical agents are Believability, Emotionality, Personalization, Team working, and Entertainment. The social interaction proposed model is to personalize user interaction in order to make the Mentor as believable as a virtual teacher. Mentor is moving, walking toward the student, waving her hand to grab his attention, standing in different poses to stimulate the student emotionally and make the environment a more attractive, entertaining one to motivate the student to keep on investigation. Besides, team-working is broadly supported in this approach. When the students enter the environment as a team, the stock will be defined on the group of students instead of individuals. So, Guides get rewarded in a group manner and Mentor introduces students to meet proper Guides based on a group assessment.

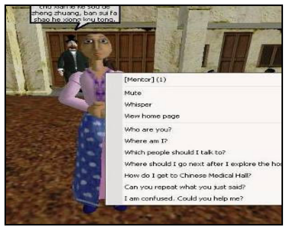
6 Conclusion

Mentor Agent is an intelligent virtual teacher to monitor the students in environment. She makes decisions on top of a Dempster-Shafer Goal-net to help student whenever she believes student has lost the clues and needs help. Proposed model provides a more dynamic, user-aware, and context-aware virtual learning environment where the users would get much more attractive personalized experiences.

Extensive experiments show that students have found this agent augment virtual environment a dynamic entertaining personalized experience with believable virtual guides.

As the possible future trends, utilizing agent technologies, broadening the bandwidth of communication, and getting the results of cognitive researches can accelerate moving toward what founders of Intelligent Tutoring Systems envisioned at the inception of the field. Pedagogical agents as a multidisciplinary research in computing, pedagogy, cognitive science, networking, and human communication requires further collaboration of animators, cognitive scientists, linguistics, and experts in the art and profession of teaching. These efforts can lead to develop believable human-like pedagogical agents.

(a) Mentor is walking toward the student, calling his name, and waving her hand to grab his attention.



(b) Mentor is in "Q & A Mode" waiting for getting student's question.

(c) Mentor is in "Informative Mode". She is providing information for student.

(d) Mentor is in "Not to Disturb Mode", has finished helping the student. She is leaving the student.

Fig. 7 Snapshots of interaction between student and Mentor

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