Intelligent pedagogical agents for personalizing learning objects in educational environments

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2008

Ashoori, M. (2008). Intelligent pedagogical agents for personalizing learning objects in educational environments. Master's thesis, Nanyang Technological University, Singapore.

<https://hdl.handle.net/10356/13582>

<https://doi.org/10.32657/10356/13582>

NANYANG TECHNOLOGICAL UNIVERSITY

School of Computer Engineering

Master of Engineering

**Intelligent Pedagogical Agents for Personalizing Learning
objects in Educational Environments**

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A thesis submitted to the Nanyang Technological University in
fulfillment of the requirements for the degree of
Master of Engineering
2007

Acknowledgement

I have no doubt about the important role of affectivity on personal and cognitive development. I believe that all progress and advances that I acquired are partially the result of the emotional support of my friends, family members and colleagues that have encouraged me to go on and face the challenges. However, some people are directly connected with each achieved step of this thesis: I would like to express my deepest thanks to my supervisor, Dr. Miao Chunyan. She is a great example of a really affective tutor that gave me careful support and substantial criticisms when needed. I also would like to appreciate Prof. Angela Eck Soon Goh and Dr. Zhi Qi Shen for their invaluable advices on my research work. Our discussions have given me a lot of inspiration on this research. I would like to offer my sincere thanks to Dr. Habib Mirhosseini as my precious mentor. I never forget the motivating moments he used to encourage me following up my passions.

Thanks to Yundong, Jianshu, Hengjie, Guopeng, Dongtao, Meina, Huangdong, and Zhanghao for our group discussions and their permanent supports. Their friendship made my days funnier, brighter and cozier.

Thanks to functionaries of SCE secretary and NTU libraries for all services rendered. Thanks to professors and researchers of NIE who have been supporting our project with their invaluable ideas and comments. Thanks to teachers of the SCE and EEE for the knowledge passed on. Thanks to A*STAR for the IGS scholarship which helped me to make my childhood dream of living in Far East true. Thanks for their financial supports during my studies in Singapore.

I do appreciate Yundong Cai. His opinion were essential for idealizing the problem discussed in this thesis.

Beside this exciting academic life in Singapore, staying in a place too far from my hometown helped me to find a different meaning of love and loneliness. I found a different aspect of love; a charming love when Ying used to call me "my little sister", or a long lasting friendship with Suchita and Ravi. I never forget spiritual atmosphere Suchi gifted to me when I was really missing my calm light cozy home. Neri was my precious little friend. Her lovely music selection on early mornings and the pure shiny moments we had together became a bright painted dream over my memory. I never forget our adventures with Atoosa from East Indonesia to South

India. Or, the funny moments I had with Nannan especially when she couldn't control herself laughing at my terrible Chinese accent. I'd like to remember Shabnam, Pari, Narges, Shayan, and all my precious Iranian friends with the brightest moments they gifted to me over last two years. Thanks to my great friends Ying, Kia Yan, Long Dong, Jang Tao, Ghim Eng, and Angela, who made our ERLab a lovely environment plenty of friendship and happiness.

Last but not least, I give my special thanks to my lovely parents for their kind supports. I don't have words to acknowledge Elham and Alireza for their endless support and boundless wisdom. They have been my strength, my criticism, my motivator and also my best friends.

به پاس تمام زیباییهایی که برایم خاطره کردید ...

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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/grid environments, just making non-individualized teaching even more widely available. The majority of current e-learning systems treat every user equally without any fine-tuning at the learning objects. This research proposes a combination of pedagogical achievements and intelligent agents toward developing such personalized learning spaces and improving the effectiveness of learning achievements through an interactive learning environment. The presented intelligent 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. The proposed approach, however, is not limited to e-learning systems. This idea can be applied to a wide variety of application domains where personalizing the content could improve the performance. This Research is part of the project of "Agent Augmented Virtual Environment" which explores agent augmented immersive virtual and mixed world to develop and assess immersive/situated learning environments. It collaborates with the National Science Foundation funded project, "Multi-User virtual Environments (MUVES)" at Harvard. The whole project is to study (1) immersive/situated learning and (2) the ways in which agent augmented virtual environments may aid the transfer of

learning from classroom contexts into real world settings. The research team of MUVE at Harvard developed the "River City" curriculum, teams of middle school students are asked to collaboratively solve a simulated 19th century city's problems with illness, through interaction with each others, avatars, digital artifacts, tacit clues, and computer-based agents acting as mentors and colleagues in a virtual community of practice. The research team at NTU focuses on software agents, multi-agent system, and agent augmented virtual and mixed environment. The team targets to infuse agent technology into various environments and application domains e.g. agent augmented virtual reality and mixed reality etc. Taking an interdisciplinary approach, the NTU team and Harvard team collaborate with each other to explore agent mediated situated learning environment and agent mediated learning community. Precisely speaking, this approach is toward an effective negotiation protocol among self-interested mentors of an agent augmented virtual environment, Virtual Singapura, for personalizing learning process and thereafter maximizing learning achievements. The synthetic characters in this environment are augmented with advanced agent technologies in order to investigate contextual, situational, social, and emotional dimensions of virtual experiences for learning. This research is to develop an effective individualization in order to providing highly accurate personalized guides according to the student's background. Agent society is equipped by situation and location awareness which let the agents track the students during the whole process of learning. Specifically, proposed approach is an inspiration of the main concept of pricing in market-based systems combined with the belief accumulation of Dempster-Shafer theory to develop a rational society of self motivated agents who provide personalized helps for learners over the learning environment. Assessments illustrated that students who use this multi-user virtual environment can construct deep understandings of scientific concepts and develop science inquiry skills, as well as the ability to transfer or apply their

new knowledge and skills to new situations. In between, personalization has performed an effective role which has highly improved the learner performance in addition to make the students find agents as believable as virtual mentors.

Chapter 1

Introduction

”Tell me and I forget, Show me and I remember, Involve me and I understand.”,
A Chinese proverb says.

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 the ability to personalize learning to learner needs. Agent mediated e-learning systems are proposed to improve the effectiveness of learning achievements through an interactive learning environment. 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 a personalized learning process in an agent augmented virtual environment, Virtual Singapura, designed to engage and motivate students at the lower secondary level in Singapore as they learn important scientific knowledge and skills.

1.1 Intelligent Tutoring Systems

A virtual training assistant that captures the subject matter and teaching expertise of experienced trainers provides a captivating new option. The concept, known as intelligent tutoring systems (ITS) or intelligent computer-aided instruction (ICAI), has been pursued for more than three decades by researchers in education, psychology, and artificial intelligence. The goal of ITS as mentioned by Jim Ong and Sowmya Ramachandran [37] is to provide the benefits of one-on-one instruction automatically and cost effectively. Like training simulations, ITS enable participants to practice their skills by carrying out tasks within highly interactive learning environments. Unlike other computer-based training technologies, ITS assess each learner's actions within these interactive environments and develop a model of their knowledge, skills, and expertise. Based on the learner model, ITS tailor instructional strategies, in terms of both the content and style, and provide explanations, hints, examples, demonstrations, and practice problems as needed.

1.2 Pedagogical Agents

ITS as an attempt to automate personal tutors, has understanding of the subject domain to offer individualized problem-solving advice to the students. Intelligent animated pedagogical agents deliver such advice with a strong visual appeal. Animated pedagogical agents inhabit interactive computer-based learning environments and provide customized feedback to the students. 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 [2, 29]. 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.

While pedagogical agents are autonomous agents, they inherit many of the same concerns that autonomous agents in general must address [53]. Particularly, animated pedagogical agents can engage in a continuous dialog with the student, and emulate aspects of dialog between a human teacher and student in instructional settings. 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. Animated characters in the interface of pedagogical systems have become increasingly popular in the recent years. These characters are based on either cartoon-style drawings, real video or geometric 3D-models [3]. They may either inhabit a virtual world, or a constrained environment that consists solely of the agent.

1.3 Agent Augmented Learning Environments

As stated by Baylor [11], there is significant potential for agent augmented learning environments as a vehicle to research instructional theory for several reasons: 1) the researcher has more control over the learning environment and interactions than in a classroom setting; 2) pedagogical agents are independent objects in the system, leading to more flexibility and interactivity; 3) while a computer agent can never simulate a real human instructor, pedagogical agents can better simulate the human aspect of instruction than other computer-based methods; 4) agent augmented systems provide the potential to capture a large amount of rich data, both quantitative and qualitative (while more data is not necessarily better, the possibilities to collect useful information during the instructional process is greatly enhanced); and, 5) through designing agent augmented learning environments with

multiple agents, it allows for investigating the effect of multiple perspectives or multiple mentors.

1.4 Motivation

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/grid environments, just making non-individualized teaching even more widely available.

These days, an emerging issue in learning is the ability to personalize learning according to the learner needs. 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. Agent mediated e-learning systems are proposed to improve the effectiveness of learning achievements through an interactive learning environment. During last decade, several empirical research projects have been done into pedagogical agents, their usage, effectiveness, or limitations [3, 20, 26, 28, 30, 36]. Some of the developed agents are lifelike avatars inhabit a virtual world and some are just intelligent agents with bounded rationality to facilitate learning.

According to the experiments of the current state-of-the-art in pedagogical agents, students generally expect pedagogical agents to be believable as virtual mentors, be entertaining, easy to communicate, helpful and diversified. These challenges motivated us to develop a believable virtual mentor who collaborates with other guide agents of an agent augmented learning environment with differ-

ent abilities and different level of intelligence. Individualization and developing a personalized process could lead to dynamic adapted interactive interface through communicating with learner. When student feels that mentor agent is aware of his background and preferences, he might find the mentor agent as believable as a virtual teacher. Feeling of the presence of an aware personal mentor who is always ready to help the student decreases the probable stress and makes him feel comfortable with environment. It can motivate the students to keep browsing the learning environment as well. Such a dynamic intelligent environment could make the virtual world a more entertaining place than the conditions where students feel guide-agents are just some static avatars with a low level of intelligence and treat all the users in a similar way.

Utilizing a society of heterogeneous mentors could provide an opportunity to help and guide students with different teaching methods and evaluate student's knowledge in different evaluation techniques. This means, designing an effective negotiation protocol in such societies could effectively improve the whole process of learning. It motivates us to answer this basic question: How a society of intelligent agents can improve a learning process by providing personalized learning? This research proposes a combination of educational achievements and intelligent agents to support learners to create such personalized learning spaces. Particularly, our approach is toward an effective negotiation protocol among self interested guides of a virtual learning environment for personalizing learning process and thereafter maximizing learning achievements.

The proposed approach, however, is not limited to e-learning systems. This idea can be applied to a wide variety of application domains where personalizing the content can improve the learner's performance.

1.5 Research Objectives

There are many challenges involved in designing an effective pedagogical agent. This research is aimed to address some of the major challenging issues including *Believability, Emotionality, Personalization, Team working, and Entertainment*.

The four main objectives of this research are as follows:

- To propose a *Mentor Agent* as believable as a virtual teacher in an e-learning environment
- To design and develop an economy of pedagogical agents with efficient market-based negotiation protocols for personalization in an agent augmented virtual learning environment
- To provide an effective learner model on top of the current standards of learner modeling
- To evaluate and demonstrate the effectiveness of the proposed negotiation protocol for personalization and thereafter the effects of personalization on emotionality and believability

In this research, our main contribution is to answer this basic question: "How a society of intelligent agents provides a personalized learning process?" Our approach is to explore effective negotiation protocols to promulgate an agent based method to improve the overall performance of learning system through an efficient personalization.

Virtual Singapura (VS), an agent augmented virtual world used for prototype validation in our approach, is developed to engage and motivate students at the lower secondary level in Singapore. VS 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. Experimental and classroom research involving students learning with the VS has been designed for the secondary level in Singapore. Assessments focus on whether students who use this multi-user virtual environment can construct deep understandings of scientific concepts and develop science inquiry skills, as well as the ability to transfer or apply their new knowledge and skills to new situations.

1.6 Thesis Organization

The thesis is organized as follows. The first section of the second chapter talks about the literature review in detail. After that, in the section for “problem statement”, relative works are discussed in brief. Finally, “Discussion” section of the forth chapter provides a comprehensive comparison among a wide range of existing animated pedagogical agents. Proposed approach and modeling techniques, learner model, agent architecture, and the collaboration model between *Guide Agents* and proposed *Mentor Agent* are discussed in detail in chapter 3. Chapter 4 brings the results and the way to apply the proposed approach on an empirical application, Virtual Singapura. It talks about the technology and details of implementation especially for database architecture, agent’s structure, and integration architecture. Chapter four ends up with a discussion section which compares proposed approach with the current state-of-the-art in pedagogical agents and finally chapter 5 draws

the possible road map to follow in the future.

Chapter 2

Pedagogical Agents: State of the art

The previous chapter explains the usefulness of pedagogical agents for personalizing learning process. In this chapter, the existing methods and agent architectures for pedagogical agents in agent augmented environments are first surveyed and their limitations for personalization are identified. Thereafter, considering the current problems of the state of the art in pedagogical agents, scope of the problem is laid down.

2.1 Previous efforts on Pedagogical Agents

During last decade, lots of empirical research projects have been done into Pedagogical Agents, their usage, effectiveness, or limitations. In 1996, Herman the Bug [26] presented by IntelliMedia at North Carolina State University was a turning point in developing animated pedagogical agents. Herman the Bug is a talkative, quirky, somewhat churlish insect with a propensity to fly about the screen and dive into the plant's structures as it provides students with problem-solving advice. It is the first agent developed to inhabit virtual environments. It inhabits a

design-centered learning environment to help middle school students understand botanical anatomy and physiology. Herman The Bug is the heart of a project that focuses tremendous attention to detail in graphics, gesture logic, sequencing, and theoretical underpinnings [26, 28].

After that, USC Center for Advanced Research in Technology of Education (CARTE) in 1997 developed a 3D pedagogical agent called STEVE [20]. It was designed to interact with students in networked virtual environments for the aim of supporting the apprenticeship model of learning. It has been applied to naval training tasks such as operating engines aboard US Navy surface ships. STEVE demonstrates skills to students; answers student questions, watches the students as they perform the tasks, and gives advice if the students run into difficulties.

At the same time, IntelliMedia Project at North Carolina State University was working on COSMO [30], a 3D character that occupies the Internet Adviser for helping learners on Internet packet routing. COSMO has been used to investigate how to combine various agent behaviors in order to enhance deictic believability [30]. Andr and his colleagues at the German Research Center for Artificial Intelligence (DFKI) were working on developing an animated 3D pedagogical agent for interactive web presentations. Their pedagogical agent, PPP Persona [3], guides the learner through web-based material using presentation acts to draw attention to elements of the web pages, and provide commentary via synthesized speech.

While research group of DFKI was working on PPP Persona, A Virtual Human Presenter, JACK [36], was being developed as collaboration between Kyushu Institute of Technology and University of Pennsylvania. JACK exhibits a variety of different deictic gestures. Like STEVE [20] and COSMO [30], Presenter JACK can

point at individual elements on his visual aid. He also smoothly integrates these gestures into his presentation, moving over to the target object before his speech reaches the need for the deictic gesture.

In 1998, USC/CARTE developed their second agent, ADELE [44], to run on desktop platforms with conventional interfaces. The motivation behind the design of ADELE was to broaden the applicability of pedagogical agent technology. ADELE extends the pedagogical capabilities of STEVE [20], and applies them to a wider range of educational problems. Whereas STEVE was originally designed to operate in virtual environments, ADELE is designed to operate over the web.

Year 1999 was a golden year in developing pedagogical agents and several research projects accomplished on that year. IntelliMedia laboratory developed WHIZLOW [31] to inhabit the CPU City 3D learning environment which represents a motherboard housing three principal components: the RAM, the CPU, and the hard drive.

Beside the research projects of USC/CARTE and IntelliMedia in this year, IBM T.J. Watson Research Center developed the AlgeBrain equation solver [1] to solve equations for a particular variable. AlgeBrain is a 2D dancing cartoon which offers practice with the benefit of a coach providing advice and remediation, keeping students on track toward solution while minimizing their level of frustration.

SMART-EGG [47] was developing in University of Canterbury at the same year. It is an animated pedagogical agent for SQL-Tutor developed by using the animation toolkit of ADELE [44]. The gesture space of this agent is exploited and combined into complex behaviors to express emotions. The main role of the agent

(a) Herman the Bug

(b) STEVE

(c) COSMO

(d) PPP Persona

(e) JACK

(f) ADELE

(g) WHIZLOW

(h) The AlgeBrain client user-interface

(i) SMART-EGG

(j) MERLIN in The Prime Climb interface

(k) AutoTutor Interface

(l) Scriptable Expressive Agent

Figure 2.1: Interfaces of current pedagogical agents (1 of 2)

is to present feedback messages to the students in an interesting and enjoyable manner, to increase their motivation and subsequently, the effectiveness of learning.

As another effort in 1999, Ana Paiva and her colleagues in INESC (Instituto de Engenharia de Sistemas e Computadores) developed VINCENT [50,51] for On-the-Job training to assist the student, promote his confidence and motivate the student to learn. It provides the system with interactivity and personalization, offering to the student a tutor friend. VINCENT was designed to be part of a training system developed by the INESC institute for the Technological Shoe-Making Center.

Finally, Stockholm University/Royal Institute of Technology developed a multi-purpose agent from Microsoft easily-programmable animated character with hooks for speech recognition and synthesis [9]. The developed pedagogical agent, Cognitive Peedy [49], is a modeling tool for information system design using object-oriented analysis. The purpose of the assistant is to encourage the student to reflect and think critically. This agent built upon situated learning ideas and the cognitive apprenticeship model [24].

In the year after, USC/CARTE developed their third agent, CARMEN [33]. CARMEN is a Maternal Problem-Solving project in collaboration between USC and the clinical psychologists at six pediatric cancer centers around the US. CARMEN's problem-solving methodology, Bright Ideas, uses an animated narrative to introduce the problems of Carmen, mother of a 9-year-old son, recently diagnosed with acute lymphocytic leukemia.

In 2001, USC/CARTE designed another digital puppet agent called SKIP [45]

to improve science learning through the use of digital puppets in peer teaching and collaborative learning settings.

Like 1999, year 2004 was another golden year in the history of pedagogical agents where several research teams continued working on developing some effective agents like SIAgent [22, 45], MERLIN [13], AutoTutor [16], and Mediating Agent of MACES [19]. SIAgent [22, 45] developed in USC/ CARTE is a domain expert watches students perform a task within the Virtual Factory Teaching System, an educational factory modeling application and simulation to teach undergraduate engineering students production and inventory management. Another developed agent is the Mediating Agent of MACES [19] developed in Universidade Federal do Rio Grande do Sul. It is an educational collaborative environment modeled as a multi-agent system and pedagogically based on the sociocultural theory of Vygotsky. The main contribution of [19] is to define, model and implement an animated pedagogical agent that, by considering student's affectivity, has the role of providing emotional support and promoting the student a positive mood. In Mediating agent, the definition of the character appearance was made based on interviews with psycho-pedagogues, pedagogues and psychologists. The animated character, called PAT (Pedagogical and Affective Tutor) is a female woman with entire body.

Beside these two agents, MERLIN [13] was designed by Conati in University of British Columbia and Zhao from Simon Fraser to improve the Effectiveness of an Educational Game called Prime Climb [13]. MERLIN provides individualized instruction integrated with the entertaining nature of the games. It is a simple pedagogical agent provides individualized help by relying on a probabilistic model of the student's factorization knowledge as it evolves during the interaction.

AutoTutor [16], A tutor with dialog in natural language, as another effort in this year was developed by a group of researchers from the Institute for Intelligent Systems (IIS) at University of Memphis who are focusing on learning technologies and discourse processing. AutoTutor came in two forms: The computer literacy version was designed to help students learn basic computer literacy topics covered in an introductory course and the conceptual physics version designed to help students learn Newtonian physics. The animated agent delivers AutoTutor's dialog moves with synthesized speech, intonation, facial expressions, and gestures. Students are encouraged to articulate lengthy answers that exhibit deep reasoning, rather than to recite small bits of shallow knowledge.

MIT Media Lab in collaboration with New York University Media Research Laboratory in 2004 developed a platform for sensing and interpreting several aspects of users' non-verbal affective information and responding through a scriptable expressive humanoid agent. The platform includes integration of multi-modal affective sensors with a real-time inference engine, a behavior engine, and a 3D scriptable expressive humanoid agent within a graphical virtual environment [12].

The story of developing pedagogical agents continued the years after. Recently, USC/CARTE has developed SOCIAL PUPPET [52] as a computer engine to help soldiers learn unfamiliar languages by interacting with animated characters. For this project, the researchers have used their expertise in previous video-games used by the armed forces, such as "Tactical Iraqi" [23, 32]. While previous games were focused on teaching language and customs, SOCIAL PUPPET is giving on-screen characters human non-verbal communication behaviors.

(a) SKIP

(b) User-interface in VS

(c) PAT, The animated character of Mediating Agent

(d) Social-Puppet interface

(e) User-interface in Quest Atlantis

(f) Users choice of thoughts for CARMEN

Figure 2.2: Interfaces of current pedagogical agents (2 of 2)

Center for Research on Learning and Technology (CRLT) at Indiana University has been started developing Quest Atlantis (QA) [10] since 2001 as a learning and teaching project that uses a 3D multi-user environment to immerse children, ages 9-12, in educational tasks. It is similar to VS [15, 39] which has been developing to engage and motivate students at the lower secondary level in Singapore. Building on strategies from on-line role-playing games, QA and VS combine strategies used in the commercial gaming environment with lessons from educational research on learning and motivation.

Regarding architecture, three main architectures have been emerged for on-line generation of agent behaviors [34]. The *Behavior Sequencing Approach* is based on a behavior space, which is a library of predefined primitives (actions, Speech elements, etc). COSMO, SMART-EGG, Herman the Bug, VINCENT and WHISLOW follow this architecture. In this approach, lifelike pedagogical agents has been specified by (1) a behavior space containing animated and vocal behaviors, (2) a design-centered context model that maintains constructive problem representations, multi-modal advisory contexts, and evolving problem-solving tasks, and (3) a behavior sequencing engine that dynamically selects and assembles agents' actions to create pedagogically effective, lifelike behaviors. For example, in Herman the Bug [26], as the learner makes her design decisions, the behavior sequencing engine monitors the activity, updates the task model, selects behaviors from the behavior space, and assembles them into a multi-modal behavior stream [27](Figure 2.3). As discussed in [21], one of the biggest challenges in designing a behavior space and a sequencing engine is ensuring visual coherence of the agent's behavior at runtime. When done poorly, the agent's behavior will appear discontinuous at the seams of the behavior fragments. For some pedagogical purposes, this may not be serious, but it will certainly detract from the believability of the agent, and it

might be distracting to the student.

Figure 2.3: The Behavior Sequence Engine in Herman the Bug

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 [42], ADELE [44], and CARMEN [33] are based on. The architecture is especially suitable for immersive environments, but it requires a much higher rendering computational load. As sample architecture, STEVE consists of two components: the first, implemented in Soar [25], handles high-level cognitive processing, and the second handles sensorimotor processing (Figure 2.4). The cognitive component interprets the state of the virtual world, carries out plans to achieve goals, and makes decisions about what actions to take. The sensorimotor component serves as STEVE's interface to the virtual world, allowing the cognitive component to perceive the state of the world and cause changes in it [41, 42].

Another Approach for Architecture of pedagogical agents is *State Machine Compilation Approach* which composes behaviors out of primitives, but gener-

Figure 2.4: STEVE's architecture

ates a state machine, so that the behavior of an agent can adapt at run time to student actions. PPP Persona [2] and JACK [36] are following this architecture. PPP Persona [2] describes a presentation planner, which develops a navigation graph from given goals. A navigation graph contains all presentation units with associated durations and transitional information. The main Core of PPP Persona is a Persona Engine which dynamically controls the behavior space (Figure 2.5). The planning process starts with an abstract communicative goal where planner tries to find a matching presentation strategy, and it posts the inferior acts of this strategy as new subgoals. This presentation script is forwarded to a Persona Engine, which decomposes the persona behaviors at the leaves of the presentation plan into more primitive animation sequences. When behavior execution begins, the persona follows the schedule in the presentation plan and the result would be adaptive and interruptible behaviors [2].

Figure 2.5: PPP Persona: A presentation plan

2.2 Problem statement: Socializing Pedagogical Agents for Personalization in Agent Augmented Virtual Environments

The current state-of-the-art in pedagogical agents represents a promising step toward creating lifelike explanatory avatars for learning environments. However, significant challenges remain; 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. Students generally expect pedagogical agents to be believable as virtual mentors, be entertaining, easy to communicate, helpful and diversified. Regarding personalization, some of the current pedagogical agents like ADELE [44] are suffering from lack of providing proper helps for students who face with problems. These kinds of pedagogical agents are informative agents who only provide and present information

through interacting with the learner. A strong process of learner activities should be designed which affectively lead the agent to interact with learners based on the history of students' activities as well as their preferences. Agents are supposed to be equipped with location awareness and situation awareness to trace students and provide helpful hints whenever it is required. STEVE [20] can sense where the student is and what he is looking at, and can adapt instructions. In addition to answering the students' requests for help, MERLIN [13] provides unsolicited hints to overcome the students tendency to avoid seeking help even when they need it. To decide when to intervene and what hints to provide, the agent relies on a probabilistic model of the student's factorization knowledge. However, there is still a long way to design an effective believable entertaining pedagogical agent.

Our proposed approach addresses the challenge of believability by emphasizing on personalization and designing effective negotiation protocols in an agent augmented virtual world where agents collaborate to provide the required information for an efficient personalized interaction with the learner. The society of agents are collaborating together to make the proposed *Mentor Agent* as believable as a virtual teacher in the environment.

One of the prominent features of multi-user virtual environments is the potential ability to design proper protocols and arrangements for team working. Team working could be discussed either for learners or a colony of agents. A society of agents could be definitely much more effective than individual agents when negotiation protocol is designed carefully. Not so much efforts have been spent on developing a society of agents and utilizing the benefit of heterogeneous agents dealing with a single student from different views to make up an effective collaborative interaction with the target users. Getting the benefits of efficient negotiation

protocols of multi-agent systems and applying them to the environment is a considerably high step toward increasing the learning performance in agent augmented learning environments.

As a whole word, this work is to develop an effective individualization in order to providing highly accurate personalized guides according to the students background. Agent society is equipped by situation and location awareness which let the agents track the students during the whole process of learning. Specifically, proposed approach is an inspiration of the main concept of pricing in market-based systems combined with the belief accumulation of Dempster-Shafer theory to develop a rational society of self motivated agents who provide personalized helps for learners over the learning environment.

A general view of the target learning environment used for prototype validation is provided in the next section followed by a clear outline of the envisaged approach.

2.3 Summary

As the new generation of learning technologies, pedagogical agents have made significant strides over the past few years. Although the jury may still be out on exactly what it is about pedagogical agents that leads to learning gains, the fact is that students learn from the intelligent tutoring system and some enjoy having conversations with pedagogical agent. These days the dream of having virtual teachers to help students achieve deep and useful knowledge has moved from fantasy to emerging reality. However, despite all the significant developments on believable human-like tutor, there is still a long way to go.

The proposed approach is a promising step toward individualization in virtual environments. It develops an effective negotiation protocol for personalizing guidance for students. Learner model is updated by a virtual teacher called *Mentor Agent* who monitors student's activities in environment and coordinate society to help the students effectively. The main purpose is developing a *Mentor Agent* who acts as believable as a virtual teacher in the learning environment.

Chapter 3

Toward An Affective Economy of Pedagogical Agents

3.1 Assumptions and problem definition

The main objective of this thesis is to answer this basic question: How a society of intelligent agents can improve a learning process by providing personalized learning? Our approach is to explore efficient negotiation protocols and promulgate a Dempster-Shafer based method to improve the overall performance. Particularly, a general agent called *Mentor Agent* is developed as a virtual teacher to control and monitor the entire student's progress and activities through the system. The general schema of the main problem is illustrated in Figure 3.1. The presented approach emphasized on the models required to get the personalized interface.

It is assumed that agents are location-aware. Agents are location-aware. The ability of sensing the physical parameters of the environment is considered for the agents to keep monitoring the students. They can monitor the virtual location of the students avatar in the environment. As an example, mentor agent would know

Figure 3.1: The general illustrated schema of the problem

if the student has visited the hospital and has received the Doctors advice over there. Otherwise, when agents are not able to sense the location of the students avatars in the virtual environment, they will not be able to trace and monitor the students in order to provide personalized help for them. Here, we are focusing on designing proper monitoring solutions in order to provide the students with the efficient personalized help regardless of getting involved with the low level physical features of the environments. Agents are assumed to be able to interact with each other as well as able to communicate with end-users as target learners.

3.2 Outline of the envisaged approach

A general agent called *Mentor Agent* is defined through the system which acts as a virtual teacher in the environment, controls the whole progress and activities of student. *Mentor Agent* is kind of coordinator through the system, who interacts with all other agents, *Guide Agents*, evaluates their efficiency and guides the student in all the locations as a permanent virtual mentor. Once student leaves a scene, *Mentor Agent* updates his activity and his qualification according to the feedback reported by the communicated *Guide Agents* on that location. *Guide Agents* are other implemented agents through the society whom students commu-

nicate 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* runs a credit assignment algorithm over the system. The credit assignment algorithm is the one discussed by [4,5,8]. It is like considering some kind of rewards for those agents who communicate effectively with students. *Mentor Agent* determines how useful the *Guide Agent* has acted facing with that particular student according to the feedback provided by the *Guide 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.

3.3 Modeling Technique

In specifying the agent system, a specialized set of models which operate at two distinct levels of abstraction have been considered. Firstly, from the internal viewpoint, the elements of agent architecture are modeled for *Mentor agent*. These are agent's beliefs, goals, and plans. Secondly, from the external viewpoint, the system is decomposed into *Mentor Agent* beside few *Guide Agents*, modeled as complex objects characterized by their purpose, their responsibilities, the services they perform, the information they require and maintain, and their external interactions with the focus on interaction with *Mentor Agent*. In the following sections, the proposed models of agents and learners are discussed in detail.

3.3.1 Learner Model

One of the most popular standards for modeling learner profile is IMS Learner Information Package (IMS LIP) [17]. IMS consortium maintains an International Conformance Program to provide joint collaboration between communities inter-

Figure 3.2: IMS Learner Information Package

ested in adapting the IMS specifications to their precise needs. IMS LIP is based on a data model that describes characteristics of a learner needed for the general purposes of:

- Recording and managing learning-related history, goals, and accomplishments
- Engaging a learner in a learning experience
- Discovering learning opportunities for learners

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 which are shown in figure 3.2.

Modified IMS LIP [4] has been used as a standard for defining the required parameters for user modeling in this research.

What has been considered as learner model is the one discussed in [4]. Among all the IMS LIP items, the related items to preferences are assumed to be “Activ-

ity”, “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

$$Identification = \{Name, Id, Gender, Age\}$$

$$Activity = \{Visited Places, Collected Items, \dots\}$$

$$Qualification = \{Absolutely Unfamiliar, Very Unfamiliar, Unfamiliar, Fairly Familiar, Familiar, Very Familiar, Absolutely Familiar\}$$

$$Interests = \{language, length of descriptions\}$$

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 current problem. Fuzzy representation of “Qualifications” is shown in Figure 3.3. Let’s consider $x = Familiarity$. Other linguistic variables could be defined based on below formula.

$$\begin{aligned} Absolutelyfamiliar(x) &= \begin{cases} 1 & \text{if } x = 1, \\ 0 & \text{otherwise,} \end{cases} \\ AbsolutelyUnfamiliar(x) &= \begin{cases} 1 & \text{if } x = 0, \\ 0 & \text{otherwise,} \end{cases} \end{aligned} \quad (3.1)$$

$$\text{Fairly Familiar} = \sqrt{x}$$

$$\text{Very Familiar} = x^2$$

$$\text{Familiar} = x$$

$$\text{Unfamiliar} = 1 - x$$

$$\text{Fairly Unfamiliar} = \sqrt{1 - x}$$

$$\text{Very Unfamiliar} = (1 - x)^2$$

This formula is a fuzzy representation of a sample value which we call *familiarity* here. In fuzzy logic *Absolute Truth* is considered as a fuzzy value of 1 and *Absolute False* is considered as 0. This means different levels of truth could be represented as a value between 0 and 1. In this case, *Familiarity* can be modeled like *Truth*. This means x as the familiarity has a value between 0 and 1. When it comes to absolute unfamiliar, x gets 0 and therefore x gets 1 when it represents absolute familiarity. As presented in fuzzy logic, *Very* can be modeled as x^2 . In the asked question, $0 \leq x \leq 1$ means $x^2 \leq x$. If $x = 0.3$ for example, then the student would be $(0.3)^2 = 0.09$ very familiar with the point and similarly 0.3 familiar it. It does not mean *very familiar* is less familiar than familiar. It represents that the degree of belief for the fact that student is very familiar with the point is less than the degree of belief to the fact that student is familiar with the point. Figure 3.3 is a fuzzy representation of “Familiarity” which is formulated in above formula.

As the last parameter, “Activity” is considered as the previous history of what the student has done in the system.

Figure 3.3: Fuzzy representation of “Familiarity” considered as “Qualification” in IMS

3.3.2 *Mentor Agent* from the Internal Viewpoint

Mentor Agent, proposed pedagogical agent for personalization, is viewed as the one with certain mental attitudes, beliefs, and goals, which represent her informational, motivational and deliberative states. In our architecture, *Mentor Agent* can be completely specified by the events that she can perceive, the actions she may perform, the beliefs she may hold, the goals she may adopt, and the plans that give rise to her purpose. These are captured by the following two models:

Goal Model

Goal Model describes the goals that *Mentor agent* may possibly adopt, and the events to which she can respond. It consists of a goal set which specifies the goal and event domain. Goal states used to specify an agent’s initial mental state. Precisely speaking, *Mentor Agent* is following a goal-net architecture. 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 [46] is proposed to model such complex goals of agents in an open distributed and dynamic changing environment. It is composed of four basic objects: states, transitions, arcs and tokens. The states, represented by circles, are used to represent different states that agents need to go through to reach their

Table 3.1: Sample effects of Interests: Length of Description

Action by Student	Agent's response: Variation 1 /Short Reply	Agent's response: Variation 2 /Long Reply
<i>approaches agent during 1st visit</i>	Hi < Name >, You must be here to look into the health problems of the city. Recently, many patients who came have been coughing continuously with chest pains and fever. But, I know no cure for them. Feel free to check around for clues.	Good day to you! you must be one of the junior scientists who is here to look into the health problems of the city. Recently, I have been very busy tending to my patients, many who have been coughing non-stop, and have fever and chest pains. At present, there is no cure for all these symptoms, but I am doing my very best to save them. Feel free to look around the hospital for more information and clues. If you have nothing else to ask, I shall be returning to my patients.

goals. A state is connected to other states via transitions, represented by vertical bars. The arcs, represented by arrows, are used to connect states to transitions and transitions to states. The tokens are used to present dynamic behaviors of the goal model. When a token arrives in a state, it indicates a state change on that state and the progress of the goal pursuing.

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. A higher level of composite states (goal or sub-goals) can be split into lower-level states connected via transitions. 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, choice, concurrency, and synchronization.

- *Sequential relationship* designates a direct connection in sequence from the

Figure 3.4: Transitions in goal-net

input states to the output states. For example, in Figure 3.4(a), State i is connected to State $i + 1$ via a transition. This implies that State $i + 1$ should be reached after State i is reached.

- *Concurrent relationship* specifies a concurrent occurrence between states. For example, in Figure 3.4(b), State $i + 1$ and state $i + 2$ are two concurrent states, which are achieved simultaneously.
- *Choice relationship* specifies a selective connection from one state to other states. In Figure 3.4(c), State i is connected to State $i + 1$, and state $i + 2$. This indicates agent may choose to proceed from State i to State $i + 1$, or from State i to State $i + 2$. The goal-selection mechanisms are used to solve the conflicts introduced by this type of relationship.
- *Synchronization relationship* specifies a synchronization point among states. For example, in Figure 3.4(d), State i and state $i + 1$ are synchronized before the state $i + 2$.

Not only does the goal-net model the complex goal of grid service agents, but

also presents a goal hierarchy from which a multi-service-agent system infrastructure can be derived. It provides a systematic method for modeling the complex goal of grid service agents, decomposing the goal hierarchy into multiple sub goal hierarchies, identifying agents, assigning goals for each individual agent, and coordinating agents toward the common goal.

Mentor Agent is following a goal-net architecture shows in Figure 3.5. In each state, agent needs to decide on one of the possible states to follow. Decision making would be based on the agent's beliefs. Belief Model is described in detail in the following section.

Figure 3.5: Goal-net with the alternative storylines

Belief Model

A Belief Model describes the information about the agent's belief to decide and plan for goal permutation in her goal model. The decision making process for goal-selection is proposed on top of Dempster-Shafer belief accumulation [38, 43]. The Dempster-Shafer theory is a mathematical theory of evidence based upon belief functions and plausible reasoning, which is used to combine separate pieces of information (evidence) to calculate the probability of an event. The theory was

developed by Arthur P. Dempster and Glenn Shafer. 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 through giving several allocations of belief to the same set of events could present a natural way of combination to give a fused allocation of belief that deals both with ignorance and with conflict between the original beliefs. In this way, it is possible to derive Belief and Plausibility for the ensemble for the purpose that makes it a base for decision making over more comprehensive information.

Theory 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 $m : 2^\theta \rightarrow [0, 1]$ is called a *basic probability assignment* if it satisfied

$$m(\phi) = 0 \text{ and } \sum_{A \subseteq \theta} m(A) = 1 \quad (3.2)$$

The quantity $m(A)$ is defined as A 's *basic probability number*. It represents the strength of some evidence; our exact belief in the proposition represented by A .

Here, frame of discernment is considered based on “Qualifications” where mass function, $m(Student_i)$, is the fuzzy amount of “Qualification” for that target student over the system.

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 is

one and only one basic probability assignment corresponds to each belief function. Conversely, there corresponds to each basic probability assignment one and only one belief function. They are related by the following two formulas:

$$Bel(A) = \sum_{B \subseteq A} m(B), \text{ for all } A \subseteq \theta \quad (3.3)$$

$$m(A) = \sum_{B \subseteq A} (-1)^{|A-B|} Bel(B) \quad (3.4)$$

Thus a belief function and a basic probability assignment convey exactly the same information. Evidence may be combined using Dempster-Shafer theory. Let m_1 and m_2 be basic probability assignments on the same frame, θ , and define $m = m_1 \oplus m_2$, their *orthogonal sum*, to be $m(\phi) = 0$ and

$$m(A) = K \sum_{X \cap Y = A} m_1(X) . m_2(Y) \quad (3.5)$$

$$K^{-1} = 1 - \sum_{X \cap Y = \phi} m_1(X) . m_2(Y) = \sum_{X \cap Y \neq \phi} m_1(X) . m_2(Y) \quad (3.6)$$

when $A \neq \phi$. The function m is a basic probability assignment if $K^{-1} \neq 0$; if $K^{-1} = 0$ then $m_1 \oplus m_2$ does not exist and m_1 and m_2 are said to be *totally* or *flatly contradictory*.

As discussed in goal model, agent decides on one of the possible three states illustrated on Figure 3.9. Decision making would be based on the agent's beliefs calculated by:

$$Belief - Agent(Student_i) = \sum m_A(Student_i), \text{ for all } A \subseteq \text{"Qualifications"} \quad (3.7)$$

This means agent decides based on the performance of students. As an example, it could be interpreted as whenever $Belief - Agent(Student_i)$ is less than the predefined threshold, *Mentor Agent* approaches the student provides some information about the current scene or asks the student if he needs help. Otherwise,

agent does not disturb the student. A generic help provides examples, formulas and explanations for pedagogical subject. The specific help is a personalized help for the student based on his learner model. The student can deny the help offered by the agent, but the agent always accept the help asked by the student. As the agent is a lifelike agent, it can present animations and messages of motivation and encouragement to the student.

3.3.3 *Mentor Agent* from the External Viewpoint

In agent augmented virtual environments, there might be heterogeneous mentors with different level of intelligence and different abilities. Our proposed approach advocates the decomposition of agent society based on the key roles in VS as the target application. The identification of roles and their relationships guides the specification of the agent class hierarchy. As discussed, we have considered two different roles in our approach; include: *Mentor* and *Guide*. Analysis of the responsibilities of each agent leads to the identification of the services provided and used by the agent, and hence her external interactions. *Mentor agent* is like a virtual teacher in environment who coordinates and collaborates with all the other *Guide Agents*. While focus here is to develop a believable *Mentor agent*, interaction model will focus on the relation between *Mentor* class and class of *Guide Agents* and will assume that different architectures of other *Guide Agents* is determined in system.

Interaction Model

Mentor Agent is kind of coordinator through the system, who interacts with all the other *Guide Agents*, evaluates their efficiency and guides the student in all the lo-

cations as a permanent virtual mentor. Once student leaves a scene, *Mentor Agent* updates his activity as well as his qualification according to the feedback reported by the communicated *Guide Agents* on that location. *Guide Agents* are all other implemented agents through the society whom students communicate with in each scene to find out the problem of the environment.

Based upon how effective the other agents have influenced the students, *Mentor Agent* runs a credit assignment algorithm through the system. It is like considering some kind of rewards for those agents who communicate effectively with students. *Mentor Agent* determines how useful the *Guide Agent* has acted facing with that particular student according to the feedback provided by the *Guide Agent*. Thereafter, next time when the student asks mentor where to go to investigate, the mentor will suggest him those areas and those effective agents with a higher probability.

A. Updating the learner model

$m(Student_i)$ as a measure of student's progress would be updated based upon the different permuted states, locations, facing with agents and the results of taken exams. Student's performance is updated in two situations through the environment. First one is the time student leaves an especial location like Hospital or Market Place. Student's performance would be updated by *Mentor Agent* based on the feedback provided by communicated *Guide Agent*. Below equation shows the way to update the $m(Student_i)$.

$$m_A(Student_i) = \alpha * m_A(Student_i) + \beta * A_A(Student_i) + \lambda * E_A(Student_i), \quad (3.8)$$

for all $A \subseteq \text{"Qualifications"}$

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 (Figure 3.6). As an example the time each student has spent on each phase can be considered as a parameter of learning.

Figure 3.6: Agent collaboration in updating the learner model

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. Results would be mapped to the student's performance by the below formula.

$$m_A(Student_i) = \alpha * m_A(Student_i) + \rho * T_A(Student_i) + \lambda * E_A(Student_i), \quad (3.9)$$

for all $A \subseteq \text{"Qualifications"}$

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.

B. Evaluating the efficiency of Guide Agents

Mentor Agent determines how useful the *Guide Agent* has helped that particular student according to the feedback provided by both the agent and the student. Thereafter, next time when the students ask mentor where to go to investigate, the mentor suggests them those areas and suitable agents with a higher probability.

Right after completing a scene, based on how effective the other agents have influenced the students, *Mentor Agent* runs a particular credit assignment algorithm through the society. In this approach, student is considered as a task through the system and a particular stock amount of the task would be assigned to the *Guide Agents*. Whenever a *Guide Agent* talks to the student, the amounts of the stock value of that particular task would be updated for the agent. In fact, *Mentor Agent* is responsible to update the related task-value based upon the feedback provided by both the agent and the student when the student leaves that stage. The feedback provided by the student is an optional feedback.

In Multi agent systems, the main issue is achieving a satisfied performance through an effective interaction among selfish agents. So, system management emphasizes to present social strategies for organizing efficient coordination among self-interested individuals. According to systematic cognition, Interaction should be accompanied by a special additive manner causing each individual, as a member of a society, to elevate own ability through a preplanned interaction protocol. However, a well-defined social value is required to develop such this shared area thoroughly. Complexity of a dynamic MAS (multi-agent system) could be effectively governed by a market-based solution inspired of successful humanized societies. A market based MAS is any collection of software agents interacting through a price

system where prices are a medium of information dissemination and aggregation. Markets can provide effective allocation of resources for a variety of distributed environments and afford related economic analyses as a powerful tool for designing interaction mechanisms. By exploring market mechanisms for achieving efficiency in multi-agent domains, essentially we would like to know what kind of humanoid meta solutions can be utilized to improve the overall performance? And what social values may be defined as well? One of these mechanisms could be an inspiration of actual stock exchange strategies where the social value is presented by a revision of stock values defined on each task of MAS. Since total profit is along the lines of individual profits in a market economy, stock updating algorithm should be designed directly base on concrescence in social and individual rewards. In our system, guide agents of the learning environments are considered as no homogeneous agents personalized by their capability, trustiness, and diligence. They indeed act based on different strategies. Here, Mentor agent looks for the most available specialized person to assign for helping the student on that stage.

There are several different mechanisms for *Guide Agents* to evaluate the student's performance on that stage. Some of them may ask some questions from the students or want them to fill up an exam paper or just determine the performance by the time student has spent on that stage, or number of clicks or some other predefined factors related to agent's designs.

If the amount of Qualification(familiarity) factor reported by *Guide Agent* is higher than the predefined threshold, an overall reward will be applied through the society to adjust the coefficients and thereafter increase the chance of interacted *Guide Agent* during the next decision making. For credit assignment, after getting the feedback of agent, if the satisfaction is lower than the threshold, asset of the

agent would be reduced by decreasing the amounts of stocks. This is to prevent the mistake of advising this especial agent as *Guide Agent* for student during next decision making. *Guide Agents* are considered as trusty agents.

$$\forall i = Agent, j = Learner,$$

$$\left\{ \begin{array}{l} PortfolioValue(j) = PortfolioValue(j) + \theta * (Feedback(j) - \delta), \\ Portfolio(i, j) = Portfolio(i, j) + \theta * (Feedback(j) - \delta), \end{array} \right. \quad (3.10)$$

where *portfolio* is the number of stocks of each *Guide Agent*, *PortfolioValue* is the stock value of Learner, and δ is the threshold considered for minimum Qualifications. *Feedback* is the feedback-value reported by communicated *Guide Agent*. Once a satisfaction degree is higher than the threshold, asset and share-value of agent will be increased. By this formula, getting a high percentage of efficiency is increasing the amount of learner stocks devoted to *Guide Agent*. Therefore, there will be an increase in the chance of being selected during next period of execution.

Modifying *PortfolioValue* means that in case the satisfaction factor is lower than the threshold, all the society is punished for not providing a good help to student. In contrast, on condition that the feed back is higher than threshold, an overall reward is applied through the society to adjust the coefficients. By this, *Mentor Agent* could define how useful the agent society has operated in general for particular students. It is also possible to define a team of students and consider the whole team as a single task over the system to support team-working.

In this method, stock is assumed as a dominant parameter that implements

an implicit unsupervised learning over the market in order to applying both social rewards and total punishments. The stock amount can be used to determine the agents whom student has communicated with as well as how effective the agents have helped that particular student. *Mentor Agent* can refer the amount of stock devoted to *Guide Agents* for each student and advise the student the next best location to go for investigation.

Decision making function for *Mentor Agent* to decide the best helpful agent for student would be based on the previous function of agent through the system determined by the total asset which is calculated based on:

$$Suitability(Agent) =_{j \in Students} \sum Portfolio(Agent, j) * PortfolioValue(j) \quad (3.11)$$

Mentor agent will suggest the student to approach the agent with the highest suitability value.

Revision in stock values is promoting the level of *Mentor Agent's* knowledge to get a profitable decision. All shareholders profit indirectly by directing a student to a competent agent and increasing the task stock value. Consequently, market goes to have an optimal advice by reducing the probability of incompetent agents gradually.

3.4 Combination of Models for future applications

Mentor Agent, virtual teacher in the environment, follows *Belief Model* and *Goal Model* in order to get the conditions in which students probably need helps. *Mentor Agent* uses the *Goal Model* as the main architecture of her mind which proposes a combination of different states which *Mentor Agent* is supposed to pass through in a pre-planned way. After modeling the agent, in order to equip the agent with thinking ability, we need to design a model of beliefs for her to decide how to travel different states of her *Goal Model*. *Belief Model* is like a model of brain for the agent which is required to complete the agent's mind.

Beside the agent model, we need a proper model to record and trace the history of students' activities, their preferences, interest, level of their knowledge, and all the related data to the students' background. *Learner Model* is the required model for modeling the student's information in the virtual learning environment.

Mentor Agent as the main mentor for the students over the whole environment, is kind of coordinator, who interacts with all other agents, *Guide Agents*, evaluates their efficiency and guides the student in all the locations as a permanent virtual mentor. The interaction protocol is designed in *Interaction Model*. The proposed negotiation protocol in *Interaction Model* can be used to update the *Learner Model* through a collaborative channel of heterogeneous guide agents. A general view of the relation among proposed models, their input/output, and their position in the whole architecture is illustrated in Figure 3.7.

Some of the current pedagogical agents like ADELE are suffering from lack of

Figure 3.7: Schematic of the relations between the proposed models

providing proper helps for students who face with problems. These kinds of pedagogical agents are some kinds of informative agents who only provide and present information through interacting with the learner. A strong process of learner activities should be designed which affectively lead the agent to interact with learners based on the history of students' activities as well as their preferences. Agents are supposed to be location-aware and situation-aware to trace students and provide helpful hints whenever it is required. STEVE can sense where the student is and what he is looking at, and can adapt instructions. ALI interleaves its teaching opportunistically with the student's own discovery learning. To support such a tutorial style, ALI recognizes learning opportunities in a student's experiment, tests the student's results, and gently guides the student toward the learning opportunities when necessary. In addition to answering the students' requests for help, MERLIN provides unsolicited hints to overcome the students' tendency to avoid seeking help even when they need it. To decide when to intervene and what hints to provide, the agent relies on a probabilistic model of the student's factorization knowledge. Generally speaking, the majority of the previous agents in the current state of the art have utilized a rather large database of different animation states for the guide agents to show the proper feature like smiling or getting angry on a proper situation. However, they mostly still suffer from lack of an emotional model

which supports the way to choose and design the proper action, animation reaction, personalized voice or so on. For a fully personalized environment, emotional agent should be designed carefully to make an adapted decision to the students feelings and preferences.

The agent models proposed here could be utilized as the personalization model to connect to such kind of databases and is in fact a general collaborative personalization model to support all the other application whose focus is on all types of personalized audio-visual interfaces. Proposed approach is compared particularly with most of the previous pedagogical agents in the next chapter.

Our proposed approach could be used wherever there is a society of agents to personalize a concept. This idea is not limited to e-learning systems and can be applied to a wide variety of application domains where personalizing the content could improve the performance.

3.5 Sample modeling: Personalization in Virtual Singapura

As the sample application, *Mentor Agent* is modeled in a sample agent augmented learning environment which is discussed and explained specifically as an empirical study in the next chapter. VS is a virtual environment with different scenes where a society of guide agents are available to help the student. *Mentor Agent* is considered as the virtual agent on that environment who evaluates other *Guide Agents* and suggest the most suitable agent to students to get help from. An overall view of the negotiation channel is illustrated in Figure 3.8.

Figure 3.8: Schematic of the negotiation channel among agents and the student

Mentor Agent is following a goal-net architecture. Based on the goal-net, three different modes of activities have been considered for the agent to follow (Figure 3.9). 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 and then provides corresponding answers. Finally, the third option would be the state where agent feels that student really does not need her and decides not to disturb the students.

Figure 3.9: Goal-selection for *Mentor Agent*

In Question-answering mode, *Mentor Agent* provides some questions for the student to choose. List of the questions is considered static to prevent the problem of Natural Language Processing. However, the answers are personalized dynamic answers. Table 3.2 shows sample questions which are listed by *Mentor Agent* for students in “Q & A” mode.

Table 3.2: Question-Answers provided by *Mentor Agent* in “Q & A” mode.

Questions by Student	Answers by <i>Mentor Agent</i>
Who are you?	I am <i>Mentor Agent</i> , The virtual teacher here to help you :)
Where am I?	You are at the < <i>Location</i> > in the Virtual Singapura. There are maps around in the city that shows your current location. You can click on any of the labeled locations in the map to teleport to that place in the city.
Which people should I talk to?	When you approach people whom you can talk to in our city, your cursor will change. On the flipside, your cursor will not change for people in our city who prefer not to interact with others.
Where should I go next after I explore here?	You can approach any of the agents and information objects within this city to find out clues to where you could go next. Alternatively, you could consult your laboratory notebook or teacher if you are still unsure what to do.
How do I get to < <i>location</i> >?	From here, you could < <i>directioninformation</i> > or just click on the maps in the city for help.
Could you repeat what you just said?	You can click on the vertical scroll bar of the chat window, and scroll upwards to see what I said to you previously.
I got confused. Could you help me?	You are < <i>Qualification</i> > with the problem of environment. You'd better talk to < <i>Guide Agent</i> > at < <i>Location</i> >.

Using *Interaction Model*, *Mentor agent* suggests the student to approach the agent with the highest Suitability-value. When *Mentor Agent* is in “Q&A mode” and student chooses this question: “*I am confused. Could you help me?*”

The answer is: “*You are 'Qualification' with the current problem of environment. You'd better talk to 'Agent' at 'Location'.*”. *Qualification* is the defuzzified value of the maximum membership of qualification. *Agent* is the name of the agent

with the highest suitability-value and *Location* is the location of that agent comes from Database. The structure of Database is discussed in detail over next chapter. Figure 3.10 illustrates the schematic of this personalized interaction with the student.

Figure 3.10: A sample schematic of interaction with learner in VS

Proposed approach is completely applied and implemented in VS as an agent augmented environment for learning. The details of implementation and the required low-level architectures for the sample case is discussed in next section.

3.6 Summary

Personalization in virtual learning environments is the system ability to provide individualization and a set of personalized services such as personalized content management, learner model, or adaptive instant interaction. The intelligent agent technology has potential regarding the creation of such personalized, adaptive and interactive e-learning applications. However, most of the available solutions have so far focused on porting existing courses with traditional teaching methods onto the

virtual environments, making them available in an attractive animated interface without any fine-tuning and adaptation to the learner needs. This work proposes a novel market-inspired collaboration model where the agents are self-interested autonomic elements collaborate to achieve a comprehensive learner model. Mentor agent makes decisions on top of a Dempster-Shafer belief accumulation to help student whenever she believes student has lost the clues and needs help. With situation-awareness, agents monitor and track the student in environment.

Chapter 4

Case Study: Personalization in Virtual Singapura

4.1 Learning Environment

This case study is defined as part of the project of “Virtual worlds and intelligent agents for learning science: Innovative technology and pedagogy for Singaporean schools” which explores agent augmented immersive virtual and mixed world to develop and assess immersive/situated learning environments.

The purpose of this project is to conduct research into how multi-user virtual environments may be used to engage and motivate students at the lower secondary level in Singapore as they learn important scientific knowledge and skills. This international project builds upon the ongoing *River City* research project at Harvard University as part of collaboration with computer engineering scientists at Nanyang Technological University(NTU) and with researchers at the Singapore Learning Sciences Laboratory (LSL). This project is developing a Singapore version of the existing US River City environment in which the synthetic characters

in the new virtual environment is augmented with advanced agent technologies developed by the NTU research group in order to investigate contextual, situational, social, and emotional dimensions of virtual experiences for learning.

Virtual Singapura is an educational environment where students can access virtual architectures configured for learning, interact with digital objects and represent themselves by graphical avatars and of course communicate with each other. VS proposes a graphical multi-user virtual environment with deep content and challenging activities where as the sample story, intelligent agents are helping 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. In the current story, students as the concurrent users may experience four different scenes include hospital, health ministry, village, and mystery house.

Beside all of these, through the collaboration, students may share their experiences to help each other to complete the investigation. Through VS, exploration is strongly open and intelligent solutions are helping to provide an effective interactive learning environment. Some entertainment and communication media, which students use outside of school, are utilized in this project to enhance students' motivation and learning about science and its impact on society. Instead of being designed for use in a classroom context, supplemented by conventional instructional activities such as textbooks and teacher-led discussions, the module is controlled by the goal oriented software agents, represented as bots in the virtual world. This project enables multiple simultaneous participants to access virtual contexts, to interact with digital artifacts, to represent themselves through avatars, to communicate with other participants and with computer-based agents, and to

enact collaborative learning activities of various types. Guided inquiry and mentoring using instant messaging with instructor avatars, virtual contexts and digital artifacts that directly and implicitly guide learner investigations can promote students' curiosity, enthusiasm and performance.

The main goal of the Virtual Singapura is to teach students the skills necessary for scientific inquiry that are important in order to understand more deeply the nature of 21st century science. Hence a topic of Dengue Education was chosen as the theme of the learning module. The virtual world has been gripped with a "Mysterious disease", Dengue, which is a prevalent disease in the equatorial part of the world.

The scenario aims at providing the students an intriguing and exciting way of learning about the dreaded disease, Dengue. Students log into the universe as teams and interact with the goal oriented agents of the system (represented by different bots) in the world. On the basis of the information provided in the worlds through these bots, the students are not only supposed to acquire in-depth knowledge about the dengue disease but also to apply it in a case study to provide suggestions of controlling the same. The scenario motivates the students to actively investigate the various statistical information and situational data to gain a complete understanding of the disease. Through VS as a virtual environment, students are required to observe the case closely, interact with the various agent-driven bots, and collect information regarding different aspects of the disease. Assessments are carried out toward the end of the module to test the students understanding of the case. Previous scenario and the primitive prototype of VS is implemented by Final year undergraduate students of NTU [39] and [15].

The seven current zones of the environment are Hospital, Market Place, Harbour, Chinatown, Medical School, European Town, School. Students can freely go through and communicate with the residents of these areas. Hospital and Market Place is completely implemented. Map of the town and snapshots of zones are brought up in below figures:

Figure 4.1: Snapshot of Hospital

Figure 4.2: Snapshot of Market Place

The current implemented agents of this environment are three agents implemented for Hospital:

- Doctor (Indian) [male] Dr Vijay Rajabali
- Nurse (Malay) [female] Nurse Siti Izura Ahmad
- Sick Coolie (Chinese) [male] Teo Kim Wah

Looking at technology, the autonomous agents are created using the Multi-Agent Development Environment (MADE), which is a goal oriented agent development framework built on top of JADE (version 3.2). The Active Worlds Educational Universe (Version 3.6) is used as the Multi-User Virtual Environment (MUVE). The virtual bots are developed using the Active Worlds Software Development Kit Version 3.6 (Build 41), which is based on C language. Caligari

Figure 4.3: VS MAP

TrueSpace (version 3.2) has been used to design some 3D graphics to be embedded into the virtual world. Eclipse 3.1 is used as the IDE for the project development. The databases are designed in Microsoft Access/MySQL. PHP enabled web pages are used for the assessment purposes and are hosted using the open source MySQL/Apache server Wamp5 (PHP 5 - Apache 2 MySQL 5).

4.2 Database Architecture

The table structure with the related columns has been considered as follows in Figure 4.4.

There are three main entities in system: “Student”, “Agent”, and “Place”. Since the relation between “Agent” and “Student” is many-to-many and also the relation between “Student” and visited places is one-to-many, two temporal tables are considered to cover this relations: “Student-Agent” and “Activity” which is in fact “Student-Place” table. Tables are implemented in MySQL.

Figure 4.4: Architecture of database

4.3 Goal-Net Structure

For goal-net management and implementing the goal-net architecture, a goal-net description is required. What we have utilized is an idea of the goal-net management proposed by [14]. There are two key components in a goal-net include states and transitions. Therefore, the most direct way to describe a goal-net is to specify what states and transitions it has and how these states and transitions are related and connected. There are four classes to represent and process and process the goal-net: (1)Goal-Net, (2)State, (3)Transition, and (4)Task. Tasks are the functions defined on each state to be executed when the state is permuted. Table 4.1 lists the properties of the *Goal-Net* class. This class supports the Meta information of a goal-net. Table 4.2 lists the basic properties of the abstract *State* class. Table 4.3 is the task list of the tasks which are executed when each state is permuted.

Figure 4.5 shows the mentor architecture designed by *Goal-Net Designer* which rises on top of the architecture for goal-net process proposed by [14]. Goal-net process is illustrated in figure 4.6.

Table 4.1: Goal-Net class

Column Name	Data	Description
Goal-Net-Id	Number	Unique identification of a goal-net
Start-State	Number	Identification of the Start State
End-State	Number	Identification of the End State

Table 4.2: State class

Column Name	Data	Description
State-Id	Number	Unique identification of a state
State-Name	Number	Name of a state
Input-Transitions	Number	Array to Store input transition
Output-Transitions	Number	Array to Store output transition

When *Mentor Agent* starts processing the goal-net, it will first load a goal-net from the database. Above data of the explained four tables are stored in a databased implemented with *Microsoft Access*. Thereafter, *Process Unit* calculate all the next possible *states* and sends them to *Control Unit*. *Control Unit* calls *Computing Unit* for goal- selection. *Computing Unit* is the place where our proposed belief-based goal-selection resides. Based upon the selected goal, *Control Unit* asks *Process Unit* for the transitions that can reach the selected goal and thereafter sends the tasks assigned to the selected transition to *Action Unit* to execute. *Action Unit* executes the given task by dynamically invoke the task function, and sends acknowledge to *Control Unit* once the task is done. *Control Unit* transits from its current goal(state) to the goal it has just reached, and asks *Process Unit* for the next goals and the cycle will be continued.

4.4 Integration Architecture

Guide Agents of the system are running within MADE(Multi-Agent Development Environment) and are following goal-net architecture. *Mentor agent* is also running

Table 4.3: Transition class

Column Name	Data	Description
Transition-Id	Number	Unique identification of a transition
Transition-Name	Number	Name of a transition
Tasks	Number	Array to Store tasks

Figure 4.5: Goal-net architecture of *Mentor* in Goal-Net Designer

within MADE but using her Dempster-based mind module for goal-selection, beside proper connections to database for retrieving and updating learner model as well as the agent model for other *Guide Agents*. Figure of system architecture of *Mentor Agent* within Virtual Singapura is shown in Figure 4.7

MADE agents and Active Worlds SDK are both having an interface written in C++. Active World SDK is a set of program interfaces to configure and control virtual world platform. SDK is responsible to execute agent's tasks into the virtual world and passing system events to agents to handle. SDK itself does not provide any decision making in the learning flow control.

Figure 4.6: Goal-net process

Figure 4.7: Integration architecture

Finally AWEDU Platform provides the 3D environment of Virtual Singapura. It gets the commands from SDK to execute and apply on graphical virtual world. Besides, AWEDU is responsible to generate proper events to report and reflect user's actions over the environment.

4.5 Some illustrative scenarios

In order to better understand how the *Mentor Agent* selects an affective tactic and the behaviors that compose it, let’s see some illustrative scenarios. As discussed

previously, *Mentor Agent* uses learner model to provide affective help messages for students.

Let's imagine that a student who is not familiar with the environment has been browsing the world for a long time without exactly knowing where to go and what to do in the environment. In this situation *Mentor Agent* approaches the student and presents a message to increase the student's attention about the problem and things which are expected from the student to do (Figure 4.8(a)).

If student accepts *Mentor's* help and keep on listening, *Mentor Agent* would provide some information regarding the environment for the student (Figure 4.8(b)). It is also possible for the student to ask specific questions from the *Mentor Agent* by clicking on her avatar. Question-list is static but the answers are dynamic personalized answers adapted to the learner model. Figure 4.8(c) shows the *Mentor Agent* in her "Q&A" mode of action. It is also possible for the student to call *Mentor Agent* by whispering her whenever the student feels he needs her helps. In this case *Mentor Agent* approaches the student with a behavior similar to what has been shown in Figure 4.8(b). After providing help, *Mentor Agent* leaves the student and goes to check if other students of environment need help (Figure 4.8(d)). Figure 4.8 illustrates a general view of the graphical interface of the way *Mentor Agent* provides help for students.

Besides, Figure 4.9 shows the events in the educational environment which are caused by the *Mentor Agent*. The student can ask for help or *Mentor Agent* can decide to offer some help to the student. This help can be specific or generic. A generic help provides examples, formulas and explanations for pedagogical subject. The specific help is a personalized help for the student based on his learner model.

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

(b) *Mentor* is in “Informative Mode” providing some information for student.

(c) *Mentor* is in “Q & A Mode” waiting for getting student’s question.

(d) *Mentor* is in “Not to Disturb Mode”, has finished helping the student. She is leaving him.

Figure 4.8: Snapshots of interaction between student and *Mentor Agent*

The student can deny the help offered by the agent, but the agent always accept the help asked by the student. As the agent is a lifelike agent, it can present animations and messages of motivation and encouragement to the student. The system is available on the Internet. This way, the student must login each time he desires to use the system.

When student approaches other *Guide Agents* in different locations of virtual world, after talking to *Guide Agent*, they whisper the student’s feedback through a message to *Mentor Agent* to update the database. Figures 4.10 illustrates some

M E N T O R A C T I O N S	Help	Agent offers help	Student denies agent's help Student accepts	Specific Help Generic Help
		Student asks for help	Specific Help Generic Help	
	Message	Agent present a message of encouragement and motivation to the student		
	Behaviour	Agent presents a sequence of animations that aims to encourage, motivate and create a positive mood in the student. This behaviour is usually followed by a message.		

Figure 4.9: *Mentor Agent's actions*

shots of interaction with other *Guide Agents* in VS.

(a) *Guides* are interacting together in front of student to provide information for him implicitly.

(b) *Guides* are waiting for students to enter Chinese market and provide information for them.

Figure 4.10: Snapshots of interaction between other *Guide Agents*

4.6 Discussion

The evaluation metric for user experience in the interactive virtual learning environment is a subjective matter. Based on [35], user experience can be evaluated in three categories of (1)Immersion, (2)Agency, and (3)Transformation. “Immersion”

is the feeling of the user to be involved in the virtual environment, able to interact with the environment and pedagogical agents. 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 development. Monitoring students activities, *Mentor Agent* collects the feedback from the *Guide Agents* to provide personalized advices, and necessary instant messages. *Mentor Agent* offers the best *Guide Agents* that student can approach to get the best reply. Students have found *Mentor Agent* believable and quite entertaining.

“Agency” is the feeling that empowers the user to take actions in order to fulfill his intension. In our dynamic world, the user is able to make some actions (such as hiding the cup for getting water sample). The *Mentor Agent* is aware of all these actions and provides advices based on all these previous possibilities. It means student can change the world and user-awareness with context-awareness helps *Mentor Agent* to monitor all these actions and adapt the future guidance to these changes.

“Transformation” means the variety of the story presentation. Different user may experience different story path to talk with different *Guide Agents* and visit different scenes as the *Mentor Agent* reasons about the user characteristics.

According to the experimental results, 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 in this research is to personalize user inter-

action in order to make the *Mentor Agent* as believable as a virtual teacher. *Mentor Agent* 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 investigating. Besides, team-working is broadly supported in this approach. When the students enter the environment as a team instead of individuals, the stock will be defined on the group of students instead of individuals. So, *Guide Agents* get rewarded in a group manner and *Mentor Agent* introduces students to meet proper *Guide Agents* based on the group assessment. To sum up, proposed models provide a more dynamic, user-aware, and context-aware virtual learning environment where the users would get much more attractive personalized experiences.

To compare different features of current pedagogical agents with the proposed approach, comparative tables of Table 4.4, Table 4.5, Table 4.6, Table 4.7, and Table 4.8 are provided. They are designed based on the comparative parameters designed by Jaques [18] where the criteria are classified into technical, contextual, and interaction. The interaction criteria identify the aspects of interaction between the agent and the student, such as appearance, emotions, etc. The technical criteria describe the technologies used to develop and execute the system. Technical point covers programming languages and operating systems of the implemented solutions. The programming language determines the portability, performance, and audiovisual resources used in the system. The contextual criteria inform the context and domain. Contextual aspect is compared in Tables 4.4, 4.5. Interactive aspect is discussed later in Tables 4.7 and 4.8. Technical aspects are brought up later in Table 4.6. Each table is filled as follows: each cell has a description about how the agent fulfills this criterion, or contains the symbol (-), which means that we did not find sufficient information about the respective aspect from the avail-

able papers.

Table 4.4: Comparative Context of Pedagogical Agents (1 of 2)

Agent	Developer	Domain	Context
Herman-the-Bug	IntelliMedia Project at North Carolina State University	Planet Caring	Microworld
STEVE	USC Center for Advanced Research in Technology of Education	Naval Training	Naval Machinery
COSMO	IntelliMedia Project at North Carolina State University	Internet packet routing	Computer Network
PPP Persona	German Research Center for Artificial Intelligence	Domain independent	Various
JACK	Kyushu Institute of Technology/University of Pennsylvania	Domain independent	Various
ADELE	USC Center for Advanced Research in Technology of Education	Medicine	Medical Chart
WHIZLOW	IntelliMedia Project at North Carolina State University	Hardware training	CPU City 3D learning environment
AlgeBrain	IBM T.J. Watson Research Center	Elementary algebra	Web based training space
SMART-EGG	University of Canterbury	SQL training	Web based training space

Technology covers programming languages and operating systems of the developed solutions. The programming language determines the portability, performance, and audiovisual resources used in the system to implement the agent. Some of these agents are portable ones developed in Java and so can be executed in any web browser which supports Java. STEVE was developed using the programming languages SOAR, Tcl/Tk, C and VRML, and it executes in the virtual environment VIVIDS. COSMO was developed for Windows platforms, since it has been implemented in C++ with Microsoft Game Software Developer's Kit. The Mediating Agent (PAT) was developed in Java and JavaScript. The character was implemented in Microsoft agent and they have used the Microsoft's voice synthe-

sizer, which are dependent of the Windows platform. The details of implementation of the other agents are provided in Table 4.6.

Animated pedagogical agents are often represented by lifelike characters which interact with objects in their environment through speech, locomotion and gesture in order to help the student with problem solving. These aspects could be analyzed in the criteria of interaction type. In relation to the character, all the agents have a visual identity which is suitable to the learning environment where they are inserted (Character's Role criterion in Tables 4.7,4.8). This comparison is based on the parameters introduced by [19] including (1)Character, (2)Appearance, (3)Communication with the user, and (4)Action.

Some of these agents are represented in entire body like animated characters of VINCENT, JACK, PPP Persona, Herman-the-bug, WHIZLOW, AlgeBrain, SMART-EGG, VINCENT, Cognitive Peedy, SKIP, Mentor Agent, Quest Atlantis' agents and Mediating Agent while ADELE, STEVE, AutoTutor, MIT's Agent and Cosmo are represented as bust. Although, a representation in entire body for these agents was not necessary, the bust representation is not believable, since it does not correspond to a real world representation (Appearance criteria in Tables 4.7, 4.8).

Another important aspect in the interaction between student and pedagogical agent is the communication mode ("Communication with the user" criterion in Tables 4.7, 4.8). Some agents like STEVE recognize speech in natural language. The interaction with ADELE is conventional and the user must choose one of the available predefined options. COSMO catches the user's actions in the interface and has 240 speech elocutions. STEVE can demonstrate tasks in the environ-

Figure 4.11: Different attitudes of Expressive Agent

Figure 4.12: Some of the attitudes of *Mentor Agent* in VS

Figure 4.13: Some of the JACK's attitudes

Figure 4.14: SMART-EGG's attitudes

ment and also interact with the user through synthetic voice, as well as ADELE, Herman-the-Bug, WHISLOW, AlgeBrain, CARMEN, MERLIN, MIT's Agent and VINCENT. VINCENT, COSMO, PPP Persona, ADELEH, Mentor Agent, and Quest Atlantis's Agents are also able to interact with the user through emotive gestures and point out objects. Presenter JACK can also point with his palm facing toward the visual aid to indicate a larger area, and he can move his hand to indicate a flow on a map or chart. He also smoothly integrates these gestures into his presentation, moving over to the target object before his speech reaches the need for the deictic gesture, and dynamically choosing the best hand for the gesture based on a heuristic that minimizes both visual aid occlusion and the distance from the current body position to the next one in the presentation. Besides, some of these agents like ADELE, VINCENT, Mediating Agent, Mentor Agent, and Quest Atlantis's Agents, beyond talking by synthetic voice, show messages in text that appear in a balloon. The student can interact with the Mediating Agent through menu options. In case of physical behaviors, STEVE presents a larger variety of physical behaviors. As an instance, STEVE shows demonstrations and explanations about the simulations to be taught and revises incorrect user's actions in the simulation with demonstrations. STEVE can also look at the student while speaking with him (it can recognize the student's vision field by the information

Figure 4.15: Some of the STEVE's attitudes

Figure 4.16: Some of the attitudes of Mediating Agent

Figure 4.17: Some of the attitudes of Herman the Bug

Figure 4.18: Some of the ADELE's attitudes

coming from the immersion equipment). STEVE can use gaze, body position, and gesture to engage the student in multi-modal dialog. Since ADELE is confined to a conventional desktop GUI interface, she has fewer options for interacting with students. ADELE's use of gaze and gesture, and her ability to react to student actions, makes her appear lifelike and aware of the user, and her use of facial expressions can have a motivating influence on a student. VINCENT and JACK have a set of audiovisual attitudes which expresses their feeling in relation to the user. COSMO can also move in direction of the objects in the system. VINCENT and COSMO make explanations when the user does an incorrect action or invite

the user to accomplish some exercise like Mentor Agent and QA's agents. ADELE only answers the user to three available options of question: Hint, How, Why (Actions criterion in Tables 4.7, 4.8) while the Mediating Agent has a large repertoire of emotive behaviors and speeches to interact with the user. Training materials developed using virtual environment typically incorporate simulated devices that respond to actions performed by the user, such as pressing buttons and turning dials. Trainees learn to perform operations and maintenance tasks by practicing those tasks on the virtual devices. Some Agents like STEVE and MIT's Agent utilizes these extra materials.

Figure 4.19: Extra equipments for Scriptable Expressive Agent

Figure 4.20: The user interacts with STEVE using a 3D mouse and goggles

Another important aspect in the interaction with animated pedagogical agents is the facial expressions, since they afford greater realism to the character, and provide another type of feedback for the user's actions, such as, disapproval, approval and wait. ADELE has a small repertoire of physical and facial gestures, and so it is somewhat static and limited. STEVE has few facial expressions, but it has good head motions. VINCENT has a substantial set of facial expressions which are integrated to its audiovisual behavior. COSMO, Mentor Agent, and MIT's Agent have also very few facial expressions. The Mediating Agent has a great repertoire of facial expressions for representing different emotional attitudes.

Regarding agent's action in the environment, by using ADELE, In the role of physicians, students are able to perform a variety of actions on the simulated patient. They may ask questions about medical history, perform a physical examination, order diagnostic tests, and make diagnoses. ADELE monitors the student's actions and provides feedback accordingly. Depending upon the instructional goals, ADELE may highlight aspects of the case, suggest correct actions, provide hints and rationales for particular actions, reference relevant background material, and provide contextual assessment to test a student's understanding. In Contrast, throughout the learning session, Herman The Bug remains on screen, standing in the plant design studio when he is inactive and diving into the plant as he delivers advice visually. In the process of explaining concepts, he performs a broad range of activities including walking, flying, shrinking, expanding, swimming, fishing, bungee jumping, teleporting, and acrobatics. Similarly, COSMO is an impish, antenna-bearing creature who hovers about in a virtual world of routers and networks and provides advice to students as they decide how to ship packets through the network to specified destinations. In response to students' problem-solving activities and questions, COSMO provides explanations in the environment. Adaptive speech, gesture, and locomotion has helped his behavior planner to create deictic references that are natural and unambiguous.

4.7 Summary

In this chapter, we explored an empirical application of personalization in interactive learning. Proposed architecture is validated by applying on Virtual Singapura, 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 interaction model where students have found the *Mentor Agent* as believable as a virtual teacher. Beside the rich graphical environment, interactions and learning scenario control are the keys for a good interactive learning system. Belief-based agent system is a promising approach as agent's natural characteristics are suitable for handling the personalized interactions with learners. The agent, modeled using goal-net with a belief-based goal-selection would empower the agent to provide helps for student especially while *Mentor Agent* is not disturbing for interfering too much.

Table 4.5: Comparative Context of Pedagogical Agents (2 of 2)

Agent	Developer	Domain	Context
VINCENT	Instituto de Engenharia de Sistemas e Computadores	Domain independent	Various
Cognitive Peedy	Stockholm University/Royal Institute of Technology	Modeling tool for information system design	A software training tool
CARMEN	USC Center for Advanced Research in Technology of Education	Medical Consulting	House and Medical office
SKIP	USC Center for Advanced Research in Technology of Education	Developing Oral Presentation Skills	-
MERLIN	University of British Columbia/Simon Fraser University	Number factorization training	Prime climb Game
Mediating Agent	Universidade Federal do Rio Grande do Sul	Domain independent	Various
AutoTutor	Institute for Intelligent Systems (IIS) at University of Memphis	Newtonian qualitative physics and computer literacy	Web based training space
Scriptable expressive agent	MIT Media Lab in collaboration/New York University Media Research Laboratory	Domain independent	various
Social Puppet	USC Center for Advanced Research in Technology of Education	Language learning	Tactical Game
Quest Atlantis	Centre for Research on Learning and Technology at Indiana University	Culture, Echology and Health training	Virtual world
Mentor Agent	Emerging Research Lab at Nanyang Technological University	Domain independent	Various

Table 4.6: Comparative Technology of Pedagogical Agents

Agent	Implementation technology	Operational Environment
MEMOLAB Agents	Allegro Common Lisp	Sun SPARCstation
STEVE	SOAR Tcl/Tk and C, VRML	Virtual Training Environment
COSMO	C++ and Microsoft Game Software Developer's Kit	Microsoft Windows
PPP Persona	C++ and Java	Web-Enabled
JACK	SGI Onyx/Reality Engine, SGI Indigo2 for voice output	Web-Enabled
ADELE	applet Java	Windows
WHIZLOW	C++/Microsoft's Speech SDK for avatar's speech/OpenGL graphics library for 3D rendering	Requires OpenGL graphics library for 3D rendering
AlgeBrain	ParcPlace-Digitalk's VisualSmalltalk/IBM's VisualAge for Java and Sun's Java Development Kit (JDK1.1)	Web-Enabled
SMART-EGG	Common Lisp,HTTP server/ Java applet	Web-Enabled
VINCENT	-	Web-Enabled
Cognitive Peedy	Microsoft Agent Package and Rational Rose modeling tool	Windows
SKIP	Java-based puppet applet	Web-Enabled
MERLIN	Microsoft Agent Package	Windows
Mediating Agent	Java, JavaScript and Microsoft Agent for the character	Windows
AutoTutor	Java	Web-Enabled
Social Puppet	-	Web-Enabled
Quest Atlantis	-	Microsoft Windows
Mentor Agent	JADE (ver. 3.2), Active Worlds Software Development Kit Version 3.6, MySQL	Web-Enabled

Table 4.7: Comparative "Interaction" of Animated Pedagogical Agents (1 of 2)

Agent	Character	Appearance	Communication with the user	Actions
STEVE	Man	3D, Bust	Natural language, user's actions in the environment, Voice	Simulates explanations with demonstrations. Monitoring the student.
COSMO	Antenna-bearing creature	3D, Bust	User's actions in the environment, Text	Explanations. Moves and points out objects
PPP Persona	MAN	3D, entire body	Text and Voice(Synthetic)	Simulates explanations with demonstrations.
JACK	Man	3D, entire body	Present audiovisual Explanations.	Explanations. Moves and points out objects.
ADELE	Female doctor	2D, Bust	Conventional (key-board), voice text (video)	Providing Hints and Explanations
Herman-the-Bug	Churlish Insect	3D, entire body	Text and Voice (synthetic)	Audiovisual gestures. Explanations.
WHIZLOW	Robot	3D, entire body	Text and Voice (synthetic)	Audiovisual gestures. Explanations.
AlgeBrain	Dancing figure	2D, entire body	Text and Gesture (synthetic)	Explanation with few gestures
SMART-EGG	Egg	2D, entire body	present feedback messages to the students	Visual gestures. Explanations.
VINCENT	Man	2D, entire body	User's actions in the environment, voice	Audiovisual gestures. Explanations
Cognitive Peedy	Parrot	3D, entire body	User's actions in the environment, voice	Audiovisual Explanations
CARMEN	Woman	2D	Text and Voice (synthetic)	Emotional Explanations.

Table 4.8: Comparative "Interaction" of Animated Pedagogical Agents (2 of 2)

Agent	Character	Appearance	Communication with the user	Actions
PAT	ADELE's body.	2D, Bust	Conventional (key-board), voice text (video)	Providing Hints and Explanations
LINDA	Woman	3D, Bust	Text	Explanation with text and Photo
Einstein ALife	Man	entire body	-	Running on a Question-and-Answer mode
SKIP	Person	2D entire body	Text with visual aids	Audiovisual gestures. Explanations.
MERLIN	Magician	3D, entire body	Text and Voice (synthetic)	Audiovisual Explanations.
Mediating Agent	Girl	2D, entire body	User's actions and menus, Text and Voice (synthetic)	Emotional Explanations
AutoTutor	Person	3D, Bust	Dialog moves with synthesized speech, facial expressions, and gestures.	Audiovisual Explanations
Scriptable expressive agent	Robot	3D Burst	Text and Voice (synthetic)	Audiovisual explanations with simple gestures
Social Puppet	Person	3D, entire body	Text and Voice	Explanation
Quest Atlantis	Person	entire body	User's actions in the environment, voice	Explanations. Moves and points out objects.
Mentor Agent	Person	3D entire body-2D face	User's actions in the environment, voice	Personalized Explanations

Chapter 5

Conclusion and Future Work

5.1 Conclusion

Personalization in virtual learning environments is the system ability to provide individualization and a set of personalized services such as personalized content management, learner model, or adaptive instant interaction. The intelligent agent technology has potential regarding the creation of such personalized, adaptive and interactive e-learning applications. However, most of the available solutions have so far focused on porting existing courses with traditional teaching methods onto the virtual environments, making them available in an attractive animated interface without any fine-tuning and adaptation to the learner needs.

According to the experiments of the current state-of-the-art in pedagogical agents, students generally expect pedagogical agents to be believable as virtual mentors, be entertaining, easy to communicate, helpful and diversified. These challenges motivated us to develop a believable virtual mentor who collaborates with other guide agents of an agent augmented learning environment with different abilities and different level of intelligence. Individualization and developing a

personalized process could lead to dynamic adapted interactive interface through communicating with learner. When student feels that *Mentor Agent* is aware of his background and preferences, he might find the *Mentor Agent* as believable as a virtual teacher. Feeling of the presence of an aware personal mentor who is always ready to help the student decreases the probable stress and makes him feel comfortable with environment. It can motivate the students to keep browsing the learning environment as well. Such these dynamic intelligent environments could make the virtual world a more entertaining place than the conditions where students feel guide-agents are just some static avatars with a low level of intelligence and treat all the users in a similar way.

Utilizing a society of heterogeneous mentors could provide an opportunity to help and guide students with different teaching methods and evaluate student's knowledge in different evaluation techniques. Designing an effective negotiation protocol in such societies can effectively improve the whole process of learning. It motivated us to answer this basic question: "How a society of intelligent agents can improve a learning process by providing personalized learning?" This research proposes a combination of educational achievements and intelligent agents to support learners to create such personalized learning spaces. Particularly, our approach is toward an effective negotiation protocol among self interested guides of a virtual learning environment for personalizing learning process and thereafter maximizing learning achievements.

This research proposes a novel market-inspired collaboration model where the agents are self-interested autonomic elements collaborate to achieve a comprehensive learner model. *Mentor Agent* makes decisions on top of a Dempster-Shafer belief accumulation to help student whenever she believes student has lost the clues

and needs help. She follows the belief model rises on top of her goal model to fulfill the expected scenario through effective path planning and goal-selection over the goal-net. Proposed architecture has been validated by applying on a sample agent augmented virtual environment, Virtual Singapura, which is designed to engage and motivate students at the lower secondary level in Singapore. Experiments illustrate the effectiveness of the proposed interaction model where students have found the *Mentor Agent* as believable as a virtual teacher.

The main contributions of this research include:

- A summary of state-of-the-art in pedagogical agents, especially regarding personalization emerged from a collaborative society of heterogeneous agents.
- A comprehensive modeling technique for personalization which covers both learner modeling and agent modeling as well as the interaction model between agents and learners.
- A personalized agent-mediated e-learning system. In this case study, we developed a highly learner-centric e-learning system where the interface between virtual mentor and end-users is personalized based on user preferences, interests, knowledge, and qualifications. Virtual mentor is location and situation aware who provides personalized interfaces to interact with learner by collaborating with the society of different guide agents.
- An interactive learning system. This system demonstrates a new approach by applying market-based interaction as one of the most effective protocols for socializing human societies to socialize heterogeneous self-interested agents. Comparing with traditional approaches, agents' natural characteristics make them more efficient in the learning scenario and interaction between the system and learners.

5.2 Future work

In spite of the reported contributions stated above, the current work can be extended in at least the following dimensions which come from the general learner desires for pedagogical agents:

- Believability.** Animated pedagogical agents are often represented by lifelike characters which interact with objects in their environment through speech, locomotion and gesture in order to help the student with problem solving. Believability is one of the main problems which lots of current efforts are suffering from. One of the emerging issues in this case is developing a question answering engine with a strong natural language processing (NLP) ability to make the agent believable. In this case, applying NLP solutions over agent augmented learning environments is an essential need which almost none of the current agents have already addressed thoroughly. Developing believable lifelike explanatory avatars is a significant challenge in current environments. *Mentor Agent* represents a promising step toward creating lifelike explanatory avatars for 3D learning environments. However, significant challenges remain; 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. Advanced graphical interfaces, text and voice with visual aids, dialogs with synthesized speech intonation, facial expressions and gestures are yet to be applied to pedagogical agents to make them as believable as virtual mentors.
- Emotionality.** Regarding communication with the learner, speech processing with focus on intelligent speech synthesis with personalized dialogs can be considered as an evolution in interaction for the future generation of pedagogical agents.

ical agents. Speech recognition deals with analysis of the linguistic content of a speech signal got from learner and reply with the artificial synthesis of speech, which means computer generated speech for pedagogical agent. New generation of pedagogical agents could even adjust the rhythm and tones of the presented speech to adopt it emotionally with the learners' needs. For a fully personalized environment, emotional agent should be designed carefully to make an adapted decision to the student's feelings and preferences. Not only should it be considered for adapted speech but also it would be similar for facial expressions and other interactive learner interfaces. Facial expressions afford greater realism to the character and provide another type of feedback for the user's actions. Experts of psychology, art, and artificial intelligence still have a long way to go altogether to provide an emotional model of expressions in facing different learners.

- **Personalization.** One of the prominent functions of pedagogical functions is personalization. In addition to answering the students' requests for help, *Mentor Agent* provides unsolicited hints to overcome the students' tendency to avoid seeking help even when they need it. To decide when to intervene and what hints to provide, the agent relies on a probabilistic model of the student's qualifications. The model is uses belief based goal net [4, 6, 7] to help the student to choose where to go in virtual environment based upon his previous achieved knowledge and preferences. Student modeling and shaping agent beliefs like what has been designed for *Mentor Agent* could be a good starting point for developing rational agents that can both stimulate learning and maintain the high level of engagement that educational games usually generate.

- **Team working.** One of the prominent features of multi-user virtual environments is the potential ability to design proper protocols and arrangements for team working. Teamwork in learning environment is the concept of learners working together cooperatively. Effective teams are an intermediary goal toward getting good, sustainable results. Team working could be discussed either for learners or a colony of agents. Only few of current pedagogical agents are designed the way that they can handle a team guide through a team of students collaborating together in the environment. In current systems, agents could help individuals, provide information for them and guide them to go forward. But, when it comes to team working and presenting a team based individualization, it is still a long way to go. Moreover, a society of agents could be definitely more effective than individual agents when negotiation protocols are designed carefully. Not so much effort has been spent on developing a society of agents and utilizing the benefit of diversified agents looking at a single student from different views. Getting the benefits of effective negotiation protocols of multi-agent systems and applying them to the environment is a considerable step toward increasing the learning performance in agent augmented learning environments.

- **Entertainment.** As the final point, grabbing learner attention and being funny enough to attract learners and motivate them to keep playing in environment is still one of the prominent desired features for learning environments. Training materials developed using virtual environment typically incorporate simulated devices that respond to actions performed by the user, such as pressing buttons and turning dials. Trainees learn to perform operations and maintenance tasks by practicing those tasks on the virtual devices. *Mentor Agent* could be attached to these extra materials. For example, the

chair that the user sits in could be instrumented with a high-density pressure sensor array and the mouse detects applied pressure throughout its usage. The user also could wear a wireless skin conductivity sensor on a wristband. Developing these kinds of accessories can definitely improve the quality of learning. Generally speaking, stories, scripts, environment, objects, agents and generally speaking the scenario which agents are following should be designed effectively to motivate learners in the whole process of learning.

Last point is the restrictions about the agent technology. A cooperative learning strategy based on an inspiration of market solutions and investiture management is proposed in this research to solve the challenge of socializing self-interested agents. According to the emerged implicit cooperative learning over the proposed approach, utilizing explicit learning approaches such as reinforcement learning as well as agent clustering seems to be effective to accelerate the market convergence to the optimum suggestion. While our credit assignment is an inspiration of real societies, this work can be continued by working on computational economies, getting their mathematical solutions and applying them over the society of agents.

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