Artificial Agents in Distance Learning

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Abstract

Consider the graphical user interface of a distance learning system, the user could click on an icon of a personal assistant to find out if appropriate human peers are available on-line to form a collaborative team, or the user could choose to click on the icon of an artificial tutor or artificial learning companion to set forth learning in a simulated learning club. Agents emerged from diverse views but converge at seeking and building software programs that engage and help the end users. There are basically two types of artificial agents in distance learning: participant agents that assume roles in participating protocols of learning activities and assistant agents that serve as personal assistants, intelligent tools, or surrogates on behalf of the end users in their absence. This paper attempts to introduce the idea of artificial agents, explore their potential uses in distance learning, and identify some of their problems.

1. MOTIVATION

With the swift advancement of network and telecommunication technology and the rapid growth of network users, distance learning bears the potential of delivering education in a much more accessible form than traditional educational settings. Furthermore, it fosters group discussion and cooperation among students that help reveal differences, promote reflective thinking, surmount egocentrism, and nurture knowledge assimilation. Thus, it is natural to ask what distance learning will be and should be, from the software point of view.

There are three objectives of using agents in distance learning. First, agents may complement deficits of most current distance learning systems. These include diminishing delayed feedback by offering immediate responses, increasing accessibility by forming learning clubs with artificial learning companions, overcoming drudgery, fatigue, and other barriers in using distance learning technology, and reducing the demand of time and effort of human teachers to run distance learning courses. Second, agents may provide a framework to meet the ends of computer based individual learning and distance social learning. There are times that individual treatments such as tutoring, simulation programs, microworld, or scaffolded learning tools are necessary even though students are engaged in distance learning activities. Third, the notion of agents may shift the focus of distance learning research from a technology-driven endeavor to the development of a more human environment for end users. By end users we mean people who use computers but are not professional programmers.

2. WHAT IS AN AGENT?

The idea of agents is not new. Names such as personal agents, software agents, network agents (or spiders), believable agents, knowbots, softbots, userbots, taskbots, intelligent interfaces, adaptive interfaces were invented to describe flavors of agents (Riecken, 1994). Because the participation of researchers across different areas, including software engineering, robotics, knowledge-based systems, databases, problem solving, planning, machine learning, cognitive science, psychology, computer graphics, art, music, film, human-computer interaction, and the like, agent research will likely draw results of many disciplines. There are several views to look at agents.

2.1 Functional View

The functional view concerns what we want or what service can be provided by agents in the near future, given the state of the art of technology. As with many other emerging ideas that intersect over different areas, researchers expect agents have a variety of functions. The following are few aspects of this view:

- An agent functions continuously and autonomously in an environment in which other processes take place and other agents exist (Shoham, 1993). This means that an agent does not require constant human guidance and intervention; thus it is proactive as well as reactive. This makes a remarkable contrast to the traditional view of the computer: a passive and programmable tool to accomplish tasks initiated by users.

- An agent may participate at its own right in some activities with the end users; more often, it acts on behalf of its owner by engaging in transactions that assume obligations on behalf of its owner in exchange of obligations assumed by other agents or end users.

- An agent may assist its owner for some specialized task; thus, it possesses some capability in a certain domain, but it hides the complexity of the task or reduces information overload. An agent can also be adaptive to its owner by receiving instruction from its owner, observing the behavior of its owner, possessing a model of its owner, or learning from other agents of other owners.

- An agent may be personified, sometimes animalized or portrayed as a cartoon, to indicate to the end user its functions and abilities. Thus, as a tutor, the agent can tutor the user; as a learning companion, the agent can learn together with the student; as a personal assistant, the agent can assist the user to achieve some task; and as a dog, the ability of the agent is limited since we do not expect much from the service of a dog.

As can be seen, the primary concern of agents is to develop software systems that engage and help end users make effective use of computers and networks of tomorrow and is a call for humanizing technological development from the inside out (Riecken, 1994).

2.2 Operational View

An agent is anything that perceives its environment and acts upon it through effectors. Operations of an agent such as its observations, actions, or memory can go at an arbitrarily fine level of implementation detail, for example, we may simulate an agent's memory as a neural map of the human brain. In our conceptualization of agents, however, we shall abstract away the physical detail and our consideration is only at the knowledge level (Newell, 1982). Next, we describe agents of several different operational complexities.

Reflex agents. Reflex agents are the simplest kind of agents, they possess only innate reflex. A reflex agent consists of a set of condition-action rules (also called situation-action rules or productions). The operation of a reflex agent can be summarized as follows. On each cycle, the agent perceives its environment, based on its set of condition-action rules, it decides an action and executes it, possibly producing a change to the environment.

Agents that have memory. An agent without memory can only select its actions based on its observations in the environment. It cannot retain useful information for making decisions at subsequent times. An agent with memory, however, will consider the state of its memory as well as observations in the environment in deciding its actions to take. At the knowledge level, only the agent's beliefs of the world and about other agents matter in deciding its actions.

Human-like agents. These are complex agents since we want to put more 'human' into them to make them human-like entities. For this to be possible, we have to ascribe *beliefs, free will, intentions, consciousness, abilities* or *wants* to a machine (McCarthy, 1979).

In the real world, multiple agents interact and communicate, using some sort of speech acts such as inform, request, offer, promise, decline, and so on.

2.3 Implementational View

Weakness or strength of agents can be revealed if one writes actual programs to implement them. A more thorough insight might be gained if investigation is at the level of designing programming languages to support implementation of agents, since conceptualization of agents at that level has to be cleansed from diversity and complexity. For example, Shoham (1993) designed an agent-oriented language, AGENT-0, which demonstrates how to model a single agent with mental components such as beliefs, capabilities, choices, and commitments. Following this line, we shall outline the design of an agent-oriented language, Carol5 (Wang et al., 1995), to illustrate how it supports the modeling of agents of possessing memory or beliefs and captures some mental qualities. This language is not the best answer for a particular model of agents, but it illustrates some generality at the design level about how agents are constructed. Readers who are not familiar with programming languages may skip this part.

To construct a set of communicating agents, we have to deal with two design issues: agent knowledge construction and agent communication. Since parts of the knowledge of the world are objective, a model of knowledge construction of agents have to incorporate a mechanism of how agents share knowledge. We adopt prototypical knowledge model (Lieberman, 1986) where everything is modeled as an object which is simply a list of attributes and the corresponding values. These attribute values are either primitive values such as integers, other user-defined objects, or method objects. Method objects are procedure objects where the body of each method is structured as a group of condition-action rules. Objects are created to form a hierarchy and if the current object needs to refer to a value of an attribute not in the current object, it will adopt the attribute value of an object upper in the hierarchy. This process is called delegation. With this prototypical object-based model, some mental characteristics of an agent can be modeled as follows. Beliefs are the object states (the current set of attribute values), capabilities are methods, and promises are run time created delayed conditional actions (or closure in programming language terminology).

Agents are subject to unanticipated events or outcomes and receive information outside themselves in the external environment at any time. Unexpected occurring of events cannot be captured by the internal states of objects. Examples of such unforeseen events include messages from other connected machines, the local user's initiated actions or orders, time, or even messages generated by other internal agents to be broadcasted to interested internal agents. In Carol5, those objects in the hierarchy that are able to handle and send events are called agents. These event handlers or senders consist of event-condition-action rules, in a way similar to methods. The interaction mechanism of agents is pretty simple. All arriving external or internal events are first kept in a queue. For each event in the queue, it is broadcasted to every agent that potentially has interest in this event, that is, its event handler consists of an event-condition-action rule of which the corresponding event is the broadcasted event. Interested agents with the condition part of the rule satisfied then execute some action, for example, calling a method, sending a new event, or making a promise. Note that the checking of the condition part with the internal environment before taking action means that the agent possesses memory. After that, another event will be broadcasted again and repeat the process until there is no event in the queue, then halt. Thus, an event resembles a working memory element in usual production systems except that events in Carol5 are volatile, they come and go after being handled.

3. SOCIAL LEARNING ENVIRONMENTS

This section gives a framework of social learning environments that assists our subsequent discussion of the roles of artificial agents in distance learning. In these environments, multiple users and/or artificial agents are involved, taking different roles and participating in some protocols of social learning activities. A social learning environment is composed of three parts: hardware and network, utilities, and learning activity.

3.1 Hardware and Network

When people from different countries are able to access databases of learning material from their homes, offices, or schools, students learning the same material will form communities to exchange ideas and support each other. If we examine the current computer-based learning environments, they can be roughly categorized into five types, in terms of hardware and network. Note that most learning techniques and strategies developed for each types, in principle, can be reused or integrated in other types.

(i) Standalone computers

This class of environments is naturally good for one-on-one tutoring or individual learning. It is also possible that a single computer can simultaneously simulate multiple artificial agents, for example, a computer tutor with one or two artificial learning companions.

(ii) Handshaking connected computers

This class of learning environments is not popular yet. They are just connected computers in short distance, say, within a classroom. For example, use R232 for PCs, and AppleTalk for Macs. Such environments, like standalone computers, can be used for computer laboratories. Also, they are good environments to develop and test distributed learning system prototypes that may be used in larger area network.

(iii) Wide area network and local area network

Research of this class of learning environments are mounting. On Internet, there are a lot of tools and resources shared globally, and the population of users are growing rapidly over the world.

(iv) Integrated cable TV and computer network

Before high speed network technology becomes mature, this type of network will be substantially used by local communities.

(v) High speed network

This type of network will be rather expensive and there are still years before they can be widely available (largely depend on the market of other services for ordinary people). Before getting a clear picture of what is the benefit of using such wide bandwidth network for educational purpose in comparing with to face-to-face classroom teaching, more experiments are needed. CoVis (Pea & Gomez, 1992) project is one of such experiments.

3.2 Utilities

Following a similar framework given by Barnard and Sandberg (1993), if we consider a learner who is at the center of the learning environment, then the learning environment consists of a set of utilities. Most of these utilities are optional, depending on the learning domain, and some of them can be merged.

(i) Other agents (besides the student)

(a) Human teacher

Teacher is a general term for someone who is responsible for teaching students and monitoring the learning activities. A teacher may broadcast messages to all students through the network as he/she does in a classroom; or may serve as a tutor or a coach for individual students. There could be many teachers on the network. We assume human teaching assistants can serve similar functions as human teacher.

(b) Human learning companions

They are learners whom the learner can communicate or cooperate during the learning process.

(c) Artificial teacher

This artificial agent takes partly the role and functions of a human teacher. In typical intelligent tutoring systems, this is the intelligent tutor who is able to diagnose students errors and offers hints when needed.

(d) Artificial learning companions

These agents participate protocols of learning activities with the learner. In network environment, if there is no other human student on-line, these artificial agents are always available to replace human students to take part in some learning activities.

(ii) Cognitive tools

Cognitive tools are a set of tools that the student can manipulate. Students use them to learn, build, construct, and test answers or solutions, and reflect what they have performed. Examples of such tools are text editors, programming language interpreters, calculators, microworlds or simulation programs, or scaffolded tools that help the student to achieve a part of the learning task. Good cognitive tools can help nurture the sense of creation, the pride of ownership, the feeling of power, and the drive for pursuing excellence.

(iii) Learning material

(a) Primary learning material

It is the material that the learner has to learn. It can be presented by means of different media: text, image, video, audio, or in the form of electronic books (multimedia hypertext).

(b) Communal database

This is a collection of comments, questions, partial answers, given by all students. Note that the content of the communal database may suggest improvement of the content and presentation of the primary learning material.

(c) Other learning resources

They are information accessible by the student, but not intended to be used in learning. For example, dictionaries, encyclopedia, electronic libraries, multimedia museum, large databases, and so on.

Thus, utilities is a tuple:

<other agents, cognitive tools, learning material>,

and an individual learning environment is a tuple:

<the learner, hardware and network, utilities>

3.3 Learning Activity

Students must undertake some sort of learning activities in a social learning environment. Activities and communications among agents are usually governed by a certain protocol of learning activities, for example, cooperation, competition, discussion, peer teaching, and so on. Thus, we may define:

Social learning environment = set of all individual learning environments + learning activity

4. ROLES OF ARTIFICIAL AGENTS

There are, unfortunately, a very few existing systems that we can look for to illustrate artificial agents for learning. Nevertheless, with the framework in our preceding discussion, we can see that the mission of agents is to enhance utilities of a social learning environment. Basically, there are two types of artificial agents in distance learning. Participant agents who are the artificial teacher and the artificial learning companions who assume roles in participating protocols of learning activities. They act as a part of 'other agents' in the framework. Assistant agents serve as personal assistants, cognitive tools, intelligent tools of the 'learning material', or surrogates on behalf of the users in their absence. As an autonomous entity, an assistant agent may share a degree of control of their own behavior from its owner. This section provides only a glimpse of the potential of artificial agents in distance learning, the discussion of the assistant agents is especially brief. However, with the growing interest in distance learning systems and when they become even more accessible, the range of roles of these agents will be broadened.

4.1 Artificial Teacher

Artificial teacher is a long standing idea since computer emerged as a potential tool for learning. The endeavor of intelligent tutoring system (ITS) research bears the vision that the computer can enact as a human teacher. Other names such as intelligent tutor, coach, or mentor refer to an agent that provides similar functions, for example, diagnosing errors and giving advice to the students. Intelligent tutoring systems are a special instance of social learning systems where two agents, namely, the human student and the artificial teacher interact in learning. The main challenge of ITS lies in the adaptability of the interaction between the student and the computer. To be adaptive, tutoring dialogue relies on a component called student model to keep track of the status of the student. Therefore, student model is a part of the world that the artificial teacher agent has to maintain. Domain knowledge such as generation of steps for a problem solution and some teaching strategies such as when and what kinds of advice to be given are also useful. Kearsley (1993) explored the implications of agents to ITS research. Distance learning can improve its accessibility by incorporating classical ITS since human teacher, most of the time, is not available to offer immediate help; even if the human teacher is there, the teacher may not be patient enough to watch how a student produces an answer step by step. Also, group learning is not always appropriate at various evolving stages of learning. For example, a student may feel more comfortable if some basic knowledge is acquired individually before participating in free discussion with other students. In many situations, whether striving for an answer individually, cooperating with another student to produce a solution on the network, or discussing a topic with a peer group, having a more knowledgeable agent which offers useful advice when it is needed is always desirable.

4.2 Artificial Learning Companion

Chan and Baskin introduced the notion of 'simulated learning companion' (Chan & Baskin, 1988). They claimed that the computer can be explicitly simulated as two coexisting agents, a teacher and a learning companion. The learning companion 'learns' together and interacts with the student under the guidance of the teacher. This addition of the learning companion gives an alternative to the traditional one-on-one intelligent tutoring system model, that is, computer can model an artificial learner as well as multiple agents, forming a small learning society where the human student may make cognitive gains. Integration-Kid (1991), the first prototype of learning companion system, explores different possible protocols of learning activities in this three-agent model in the domain of learning integral calculus. The learning performance of the learning companion in Integration-Kid is governed by a subset of problem solving expertise and some faulty knowledge. In the process of learning, this problem solving expertise is being expanded and the faulty knowledge is being tuned by simply deleting and adding knowledge units. In principle, actual machine learning can be used to model the learning performance of the companion. In both approaches, the companion is required to learn as the student does.

Most important of all, learning companion systems provide a wider view of learning environments, including distance learning, that utilizes intelligent agents: " ... the paradigm of learning companion systems represents a board spectrum of ITS design due to the possible varieties on the number and the identities of the agents in a learning companion systems. Each of these varieties gives rise to particular cognitive issues in the student's learning ... it is possible to have multiple teachers with different persona ... Learning companion system may also be a simulation of peer group learning, which means more than one learning companion with different knowledge level or persona involved in the learning environment .... Imagine in the near future as the price of computers falls and the technology of computer networks becomes more accessible, students can learn together through geographically distributed networks of computers (perhaps without a human teacher). We believe that current learning companion system research is preparing for such a *futuristic intelligent computer classroom*. In particular, learning companion system research for such a learning environment will probably focus more on the design of dynamically structuring learning activities which may be monitored by a rather passive computer teacher. (Chan & Baskin, 1988)"

In a distance social learning environment, a student with an artificial learning companion at a computer site may collaborate with or compete against other sites. An interesting type of distance social learning systems is that there may be some added *pseudo sites*. Pseudo sites are sites that do not really exist, rather, they are simulated by the server. In the extreme case where all other sites are pseudo, then the system is in reality a centralized system, that is, the computer simulates multiple artificial agents locally. Pseudo sites help increase the accessibility of distributed learning companion systems. For example, some group learning protocols such as reciprocal teaching for reading comprehension (Palincsar & Brown, 1984) require several participants to take different cognitive roles in turns. If there are not enough students on-line, pseudo sites can always serve to play the needed roles. Also, pseudo sites sometimes can help mediate the process of learning. For example, at certain point of teaching, if the teacher (computer or human) would like his/her students to raise an important issue, and unfortunately no real site students do, a pseudo site may do that instead. Finally, depending on the educational purpose of the system, students may or may not know that there are pseudo sites. If the system keeps a student model of the student, then, in the absence of this student and if this student is willing, the student may delegate an artificial learning companion on his/her own behalf to participate some learning activities with other students, using the student model. Next, we discuss in further detail the different types of artificial learning companions.

Artificial cooperator or collaborator. The role of an authorized teacher for transmitting certified knowledge has been challenged (Gilmore & Self 1988). They suggested that the computer can *cooperate* with the student in learning, instead of teaching the student. In general, a collaborator or cooperator can provide cognitive conflict and scaffolding which lessen cognitive load to other participants. Roschelle and Behrend (1995) distinguish cooperative learning and collaborative learning as two different forms of learning activities. Collaborative learning partitions the learning task into sub-tasks undertaken by different agents. It is a 'divide and conquer' strategy that allows each agent to be responsible only for a sub-task while the rest is taken care by other agents. Collaborative learning, on the other hand, involves simultaneous participation of all agents on a single task. Unless communications among collaborators are coordinated, the intensive and rather free style of their interactions make the development of an artificial collaborator difficult.

People Power (Dillenbourg & Self, 1992) is a computer supported collaborative system where the computer assumes the role of a collaborator of the student. The People Power system investigates how social dialogue generates structures for the reflective dialogue. They regard collaborating as a dialogue with the peer and reasoning as a dialogue with oneself. People Power contains a microworld in which the student can create an electoral system and simulate election. The collaborator (they call it co-learner) stores and replays dialogue patterns in communicating with the student, resulting in a sequence of mutually refuted argument patterns. The procedure uses two arguments, the proposer and the critic, and acts as a theorem prover to prove that some change in the country map leads to a gain of seats for a particular party.

An instance of cooperative learning on network is a system called Responsibility-Sharing-Kids where a triad use the system at three connected computers (Chan, et al. 1995). In Responsibility-Sharing-Kids, the learning task of solving a Lisp recursive problem is decomposed into three sub-tasks taken by the triad. The designer uses a semi-natural language to write pseudo code of the program, the executor translates the designed program to Lisp code and execute, and the critic monitors the design, translation, and execution processes. Currently, there is no incorporation of artificial agents in the system. However, an artificial agent can either replace one of the distant participants or acts as a learning companion or a private tutor to help a human participant.

Artificial competitor. Competition or inter-group competition are common in sports or commercial behavior. Also, competitive computer games where the user competes some virtual opponents are popular. For learning, a competitor is a source of motivation, a factor to determine whether the student *will* do, not just whether he/she *can* do. It is certainly appealing for a learning environment to be able to enhance a student's achievement-striving behavior. However, there is a phobia of applying competition in education because of the possible harmful social effects. Competition may lead to large incongruities in interpersonal perceptions due to the fact that students' gains or rewards are negatively related. Thus, designing learning activities that involve competition needs to be prudent.

Contest-Kids (Chan & Lai , 1995), a system for practicing declarative knowledge, involves a group of students who compete on the network. In group competition, usually a half of the population of students are always less competent than another half, based on the students' overall performance. We refer this problem the *lower half* problem. While we intend to promote every student's potential in learning, we do not want to maximize their performance differences, in particular, we do not want that every student in the lower half always feels inferior. Contest-Kids solves this problem by sneaking a set of pseudo sites or *pretend* companions into the system. Pretend companions are artificial agents that students do not know that they are virtual. The participation of these pretend companions alters the performance statistics in a way it meets the motivational needs of most real human students. This strategy challenges the sanctity of education where honesty is always honored. To be honest or not to tell the truth is sometimes a dilemma in real life. For example, it is hard for a teacher to be honest if an incapable student ask about his/her ability. Employing pretend companions, though interesting, is controversial. Besides pretend companions, Contest-Kids also uses *simulated* competitors which are artificial agents whom the students know they are simulated. The preliminary field test shows that students paid different amount of attention to simulated companions of different social attributes, for example, students noticed more about the performance of a simulated companion who was supposed to come from a famous school.

Competition, very often, mixes with collaboration. For example, multiple students on the network may collaborate to compete against an artificial competitor. Also, students may form teams to compete against each other with the help of some artificial collaborators for each team.

Artificial tutee. In the real world, most teachers know that they learn a subject better when they teach it and many professors offer new courses because they want to learn about them. Peer tutoring is also an informal learning activity adopted by some schools. Chan and Baskin (1988, p.199) suggested a protocol of learning activity where the student "learns how to learn by teaching the learning companion". This protocol inverts the model of intelligent tutoring systems, putting the student in the position of a tutor. Palethepu, Greer, and McCalla (1991) describe a system architecture in a declarative domain represented by a semantic network. Also, Ur and VanLehn (1994) apply explanation-based machine learning method to simulate a physics student for the purpose of tutor training and use it to study the cognitive process of learning from a tutor.

More recently, a set of handshaking connected systems called Reciprocal-Tutoring-Kids that supports a form of learning activity called reciprocal tutoring in solving Lisp recursive problems have been developed and tested (Chan et al., 1995). During reciprocal tutoring, two agents, where an agent is either a real student or an artificial agent, interact and take turns to assume roles of a tutor or a tutee for different problems. Thus, the student has the opportunity to learn by being a tutor and by being a tutee alternately. The student who assumes the role of a tutor will learn by diagnosing the tutee's error and giving advice. Interleaving being tutored and tutoring urges a student to work with the help of a peer and to learn by observing closely the peer's work who can be regarded as a counterpart of the peer, fostering reflection of the acquired knowledge.

These systems are being moved to Internet. Thus, if a student cannot find another student on-line to participate reciprocal tutoring, the artificial agent, being a candidate of a collaborator, is available there. In the implementation of Reciprocal-Tutoring-Kids, we found that the student model played a rather critical role and was used in three different ways: (i) to model an intelligent tutor as in usual intelligent tutoring systems to tutor the human student, so it is hidden behind the student; (ii) to be used as an important component in modeling an artificial tutee so that it looks to be learning and making mistake while being tutored by the student; and (iii) to be used in a tool manipulated by the student tutor to diagnose and give hints to the human tutee at the other end of two connected machines.

An aspect that has not been explored in Reciprocal-Tutoring-Kids is the study of an artificial meta-tutor whose job is to help the student tutor the tutee. Of course, this meta-tutor can also be taken up by another human student on the network. Also, like what we have discussed about artificial competitor above, an artificial tutee can be tutored by multiple students on the network.

Artificial group leader. For some project-based exercises, students can be organized to achieve a common goal. An artificial group leader can be designed to support, monitor, and tutor students to work together. McManus and Aiken (1995) implemented an artificial group leader on the network to assist students to work using Jigsaw method and to learn collaborative skills. In Jigsaw method, a project which contains several topics is investigated by students who are first assigned to 'expert' groups with one group responsible for a discrete topic and the production of a result. Students then are rearranged into 'home' groups so that each home group consists of different experts to produce a combined project. The artificial group leader uses scripts to define activities of participants, a finite state machine to parse script and monitor discussion state changes, a collaborative skill network to represent the interpersonal and small group interactions, a student model to record each student's collaborative attributes, and tutoring rules to determine whether a student uses the skill appropriately. Besides learning collaborative skills, such architecture is general enough to monitor students' learning activity.

Artificial roles in role playing game learning. Role playing games (RPG) are simulation of interpersonal interaction so that the user is engaged to interact with various roles in a scene. They are situated learning environments particularly suitable for learning or training in some complex situations in real life. For example, training a bank teller by having the trainee take the role of a teller, a customer, or the teller's manager, forcing the trainee to make decisions and take actions under various situations or cases. Hsu (1989) employed role playing games in distance learning environment for training management, but all roles were taken by human students. A more interesting case is that students on the network play some of the roles while the computer plays other roles with their behavior controlled by the teacher so that students' attention can be drawn to some special issues or viewpoints that the teacher wants the students to learn. Both cognitive and affective factors are important in simulating the roles in RPG. For example, we can simulate a historical incident together with several artificial roles of different background to look at the incident and give different viewpoints. However, to our knowledge, there is no commercial authoring shell for role playing games available, making implementation of such systems labor intensive; nevertheless, the emerging technology of virtual reality will arouse interest in building such gaming environments.

4.3 Artificial Assistant for Student

Personal assistants for students are desirable in many occasions. It can help students release information overload by prioritizing, sorting, filtering, and archiving electronic messages from other students. Like a secretary, an artificial assistant can help a student to schedule group meetings with other members and manage calendar. The artificial assistant may also act as a personal consultant to suggest daily plan for learning in a day. Sometimes a student needs such advice to manage learning schedule if he/she is taking multiple distance learning courses or meeting several deadlines for projects or assignments.

When a student is learning the 'primary learning material' individually or a cooperative group of students are working on the network, if impasse arises, artificial assistant can help search other students on-line who are appropriate to discuss the relevant problem, probably by consulting the assistant agents of those students. Another possibility is to send the personal assistant to search the 'communal database' for dialogues that might relate to the student's question. This matched dialogue has to be relevant to the student's understanding of the domain and illuminates similar difficulty that has been experienced by other students (Mayes & Neilson, 1995). For 'other learning resources', an artificial assistant may also be useful. It may search and navigate electronic reference books, encyclopedia, video and image library, dictionary, etc. These resources are distributed and heterogeneous and require analysis at different levels of granularity to produce useful information for the student.

4.4 Artificial Assistant for Teacher

In distance learning, the need of one or more artificial assistants for a teacher is particularly salient since the teacher is not always available on-line. Students' profiles in distance learning, including the learning activities they participated and the corresponding performance, can easily be kept in computer. By investigating and analyzing these profiles, an artificial assistant can help the teacher understand students and make suggestions. For example, an agent can help match students to participate some small group learning activity, based on the information from the profiles. If these profiles, like student models, contain detailed information, such as their errors and misconceptions, then the agent is able to give advice to students when they are learning, in the absence of the teacher. In this case, the agent is essentially an artificial tutor to the student. Of course, artificial graders, which are simpler to be constructed than artificial tutors, are also welcome by most teachers.

5. PROBLEMS

Like other areas, acceptability and achievability are two problems that artificial agents in distance learning face (Norman, 1994). As discussed in the last section, in many circumstances, artificial agents access personal records that include part of daily activities, performance, ability, and so on, leaving the privacy of the student at stake. Also, social mischief in using agents by some students are possible. In the worst case, students may take advantage of the power of these agents and modify them for destructive purpose, like computer virus. Sense of feeling of control is another issue. Artificial agents are autonomous entities of different degree, they may have their own intentions or goals to achieve and react opportunistically to the external environment. The student may feel no control of such entities. Furthermore, students may have to interact a society of artificial agents and need the ability to instruct and manipulate agents. Last but not least, do you want your agent to decide who you want to work with? All these contribute to the lack of confidence in using agents.

Another issue of acceptability is the false expectation, possibly generated by agents with multi-sensory stimuli, dynamic facial expressions, and carefully turned natural language interactions. The natural tendency of users to anthropomorphize agents will blow up their expectation. Once they discover that agents cannot possess full knowledge or ability of human, they conclude that agents are deceptive.

It is interesting to note that in both Contest-Kids and Reciprocal-Tutoring-Kids, we succeeded to fool several students by telling them that they would interact with human students; in fact, they worked with an artificial agent. Students believed that those artificial agents were human partly because students trusted us and so believed what we had told them. The rather narrow bandwidth of information communicating between students and agents clearly contributed a part of this psychological plausibility. It is also possible that students, unless we tell them, do not have a good model of artificial learning companions. This raises a question whether human tutors have good models of their tutees too.

Are artificial agents achievable? The answer is no, if one expects too much. Certainly, the computer cannot provide artificial agents at the ideal level -- with full ability of natural language understanding, learning, planning, intention, freewill, emotion, common sense, and so on. The answer is yes, if it is a reasonable goal and with considerations of the computational constraints as well as the external physical and social environments that shape learning. Thus it depends on what we want and how we get it. After almost twenty years of effort, the ability and limitation of applying artificial intelligence to education is better understood. Formidable barriers have been experienced in building artificial tutors. Since distance learning bears the promise to free learning from the constraints of space and time and adapt to the user's everyday lives, the best strategy to study artificial agents in distance learning is, perhaps, in the context of their use. As Clancey (1992) put it, "We must develop our designs in the course of use, incrementally, with relatively quick periods of use, observation, reflection, and redesign. That is, our computer systems, as artifacts that fit into people's lives, must develop our designs in a context that includes the user's everyday adaptations."

6. CONCLUSION

While there is a growing interest of using artificial agents in learning environments, there is no serious evaluation of their learning effectiveness to date. Furthermore, what aspects artificial agents may perform better than human partners still require more investigation to justify the use of artificial agents in distance learning. Yet, the notion of artificial agents can help us imagine, from the software point of view, what distance learning will look like. Looking out in the future, say, in five or ten years, a user, backed by a set of assistant and participant agents, can participate distance learning with a wider array of choices. Learning takes place synchronously or asynchronously, spontaneously or reflectively and interaction occurs not only between human and human, but also between human and agent, and agent and agent.

Finally, a few conclusions can be made about the development of the artificial agents in distance learning: (i) agent is a forceful and tangible notion to draw integration of research efforts across disciplines in future distance learning research, in particular, it helps to meet the two ends of computer supported individual learning and network supported social learning research; (ii) given a reasonable goal, usable agents for distance learning are achievable if developed in the context of their use; and, finally, (iii) distance learning, in turn, is a vehicle for productive artificial agent research since relationship among learners and teachers will last for a considerable period of time.

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