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Artificial Agents in Distance Learning

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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.

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.

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 ways to look at agents.

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 to provide a variety of functions. The following are a few aspects of this perspective:

- 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 in 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 for obligations assumed by other agents or end users.
- An agent may assist its owner in 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).

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.

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 has to incorporate a mechanism of how agents share knowledge. We adopt a 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 higher 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 occurance 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 the process will be repeated 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.

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.

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.

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.

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.

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 is growing rapidly over the world.

Integrated cable TV and computer network. Before high speed network technology becomes mature, this type of network will be substantially used by local communities.

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.

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.

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

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.

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>

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

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, 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 even greater accessibility, the range of roles for these agents will be broadened.

Artificial Teacher

Artificial teacher is a long standing idea since computers emerged as a potential tool for learning. The endeavor of intelligent tutoring system (ITS) research bears the vision that the computer can act 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