Software Agents for Facilitating Collaboration among Students in *e*-Learning

Weidong Pan
Faculty of Information Technology
University of Technology, Sydney
PO Box 123 Broadway, NSW 2007, Australia
wdpan@it.uts.edu.au

Igor Hawryszkiewycz
Faculty of Information Technology
University of Technology, Sydney
PO Box 123 Broadway, NSW 2007, Australia
igorh@it.uts.edu.au

Abstract: Computer supported collaborative learning (CSCL) is one promising technological means to support *e*-learning over the Internet. However, current CSCL systems work mostly in a *passive* fashion and do not attempt to take *active* control of the collaboration. In such systems, it is the responsibility of the participating students to organize and accomplish all the activities of collaborative learning (CL). Students get little assistance from the system during the CL, e.g. the composition of a CL group, the partition of a learning task, the combination of learning outcomes, etc. This paper seeks to actively help and guide students in the CL by software agents. The CSCL over the Internet is first investigated where some challenges for the students while they are taking part in the CL are highlighted. Based on the investigation, a multi-agent architecture to facilitate the CL is proposed. Then, the implementation in one particular CSCL system, *LiveNet*, is presented and the supports of the agents for the CL are explored. At the final are the conclusions of the paper and some outlooks.

Introduction

E-learning is the delivery of training and education via electronic media (Mohan & Greer, 2003). It has been widely recognized that *e*-learning over the Internet has many attractive characteristics, e.g. learners can access course materials anywhere and at anytime. However, some specific issues should be taken into consideration in order to ensure the effectiveness of learning because under such a learning environment, a student usually takes part in a learning process individually; he is separated from his teacher and his fellow students in geographical location. The student is more likely to be in an isolated and helpless position if he has a problem during his study. A considerable research effort has been spent to solve the problem. A variety of supports and services have been proposed and put into professional practice for this purpose.

Computer supported collaborative learning (CSCL) is one of the most significantly technological means for supporting *e*-learning. Collaborative learning (CL) is referred to a variety of learning activities that seek to promote learning through collaborative efforts among students working on a given learning task. It provides an environment to enliven and enrich the learning process and it enables students to learn in relatively realistic, cognitively motivating and socially enriched learning contexts (Kumar, 1996). CSCL delivers a virtual environment for students to take part in a learning process collaboratively.

Currently CSCL is usually implemented based on the results of research in the area of computer supported cooperative work (CSCW), where workplaces are provided for online participants to collaborative work. Such CSCL works mostly in a *passive* fashion, where the system that delivers the collaborative environment does not attempt to take *active* control of the collaborative interactions among participating students (Kumar, 1996). The system in fact only provides a platform for CL and it is left to the students to make use of the platform for the implementation of the CL. Students get little assistance from the system for the CL, more specifically, for the composition of a CL group, the partition of a learning task, the combination of learning outcomes, and student's individual learning, etc.

This paper proposes a way of utilizing software agent technology to facilitate the CL over the Internet. Software agents are integrated into a CSCL system to help participating students to make use of the platform provided by the system in effective ways to accomplish various CL activities. Software agents can be autonomous but coordinate to actively control the CL processes. They can help and guide the students to set up learning groups and accomplish the learning tasks assigned to them. In the next section the CSCL over the Internet is investigated, which highlights the challenges for the students while they are taking part in CL. An architectural framework of a multi-agent system to help the students in the challenges is proposed in section 3. The implementation of the architecture under a CSCL system is presented in section 4, where LiveNet (see http://livenet4.it.uts.edu.au/index.jsp) is used as an example of the CSCL systems and the supports of the agents for the CL on the system are explored. In section 5 the conclusions of this paper and some outlooks are presented.

The CSCL over the Internet

The workspaces in the CSCL

CL is applicable to almost all of the realistic learning circumstances. In a classroom, for example, students work together to accomplish the learning task of a topic in groups, exchange ideas and help one another. It has been recognized that CL offers many benefits to the learners, e.g. deeper understanding of content, increased overall achievement in grades, improved self-esteem, and higher motivation to remain on task. CL can facilitate students become actively and constructively involved in content, to take ownership of their own learning, and to resolve group conflicts and improve teamwork skills. Consequently CSCL has received considerable research efforts along with the emergence of multimedia, communication, and especially the Internet technology.

One essential issue in CSCL is to provide a place for participators to conduct CL. In a physical CL environment, e.g. a classroom, all the participating students and necessary tools are assembled to a physical place for the learning task at hand. In the CSCL over the Internet, a virtual place, called *workspace*, is provided as a shared place for the substitute (Harrison & Fourish, 1996). By the workspaces, participating students, no matter where they are, are able to share information with one another in their own computers, e.g. they can use the same documents or discuss the same issues. They can exchange messages one another by text, graphic images, etc.

The workspaces in the CSCL are dynamic. Students can define and continuously modify them based on the requirement of collaboration for the learning task at hand. The main notions related to the workspaces are as below (Biuk-Aghai & Hawryszkiewycz, 1999):

- *Role* describes a responsibility within a workspace, e.g. an owner, a project leader, a coordinator, etc. Roles are assigned to participants in a workspace, i.e. to individual students, which defines the actions a student is allowed to perform. A student may have different roles in different workspaces but always acts as the assigned role in a workspace.
- *Actions* are activities or operations which can be carried out in a workspace, e.g. create or delete an artifact. The actions can be grouped into two types, i.e. solo actions and interaction. The former is performed by a single role; and the latter involves multiple roles.
- *Artifacts* are any objects which are consumed or produced in an action. These are usually documents of various types, e.g. text, drawings, graphic images, etc.
- *Messages* are short text strings which are exchanged between two roles to signal the occurrence of some event. The sending and receiving roles may reside in the same or in different workspaces. Messages have a defined *message type*, which is associated with, and unique within a workspace.
- *Communication channel* permits students to communicate each other, e.g. synchronous text-based communication and asynchronous discussion forum.

Based on the notions, a virtual collaborative environment for a concrete learning task can be defined where various terms and activities related to the implementation of the task can be expressed in these notions.

The learning modalities in the CSCL

CL can be supported by several learning theories, such as distributed cognition theory, constructivist theory, sociocultural theory (based on Vygotsky's inter subjectiveness and Zone of Proximal Development) (Vygotsky, 1978), etc. Several ways of approaching CL in the CSCL over the Internet have been proposed and moved into practical applications. Depending on the supporting theory and the type of learning tasks to be performed, CSCL could be employed to address several learning modalities. The typical learning modalities include:

- *Problem-based learning* is a student-centered, contextualized approach to learning. It begins with a problem to be solved and the analysis and study of the problem comprises several phases that are spread over periods of group work and individual learning. This modality exemplifies authentic learning and emphasizes solving problem in rich context.
- *Inquiry learning* is in fact an application of database systems and information retrieving systems in instruction. It can retrieve the required information from the subject database based on the request asked by a student. Students get the answer for an instructional question through such an information service, collection of information and their own intellectual activities, e.g. synthesis, generalization, analysis, reasoning, etc. The entire learning task can be split into several sub-tasks which can be respectively undertaken by an individual student.
- *Resources-based learning* demands students learn through making use of various resources over the Internet. It emphasizes a transformation of meaning through student-centered, system-facilitated actions.
- *Case study* is a learning approach able to bring the real world into the learning environment so that students can "practice" on actual or realistic problems. An instructional case is a story about the "real world" with a definite teaching purpose. The main activities are discussion, exchange of ideas, knowledge and experience among participants (IP & Morrison, 2001).
- *Scaffolding learning* is a learning process that teachers provide and support students with scaffolds while the students develop their cognitive strategies. It is a culture that permits peers to learn through their interactions, to build stories about common experiences, and to share the knowledge building experiences with the group.

The learning procedure under the CSCL

Just like in a physical CL environment, a learning process conducted in the CSCL over the Internet goes through the following four sequential stages:

- *The composition of a CL group* is to find appropriate fellow students to study together. Although it is easy in a face-to-face CL environment, it is difficult in the CSCL over the Internet because students are separated in different geographical locations. Obviously a student has to know the activities of other students *before* he decides to whom study together. The composition of a CL group can be by self-selection, random assignment, or criterion-based selection (Gokhale, 1995). There are several criteria for selecting partners from the participating students with different learning characteristics to construct a CL group. A typical one is the mutual complement principle, which lets stronger students help the weaker ones learn and themselves learn from the experience of tutoring. The size of a group is another issue which should be considered in the composition of a CL group. It is known that a smaller group contains less diversity; and may lack divergent thinking styles and varied expertise that help to animate collective decision making. Conversely, in a larger group it is difficult to ensure that all members have enough chances to participate the activities.
- *The partition of the learning task* is a procedure of splitting the learning task into several sub-tasks and allocating each one to an individual student in the group. Clearly it should be based on the learning characteristics of each student in the group. Again it can be easily implemented while students in the group can negotiate with one another in face-to-face. It is difficult in the CSCL over the Internet because the students mostly do not know each other in terms of learning characteristics. Moreover, it becomes even more complicated while the task is a complex or an ill-defined problem in knowledge domain. In general it is necessary to take into account of the learning task at hand, the learning modality to be adopted, and the learning characteristics of each student in the group in order to partition and allocate a learning task in such a way that all of the participating students could benefit to a maximum degree in accomplishing the assigned task.
- *Individual learning* is referred to the learning respectively undertaken by individual students in the group. According to CL theories, CL comprises both the cooperation and individual learning and individual

learning is the basis for the cooperation. In the CSCL over the Internet, an individual student studies in his own computer and the learning activities are usually Internet-based. In this alone learning, the student has to solve all the possible problems by himself if he can not get effective supports from the system. Obviously it is difficult for the student although the learning task for him has a finer grain size than the one before splitting.

- *The combination of the learning achievements* is a procedure of collecting the learning outcomes achieved respectively by all individuals in the group. Obviously individual students study for a common goal and their learning achievements should contribute to the overall learning outcomes of the whole group. This procedure is very complicated while the learning task is a complex or an ill-defined problem, e.g. presenting and moderating a seminar, participating in a discussion or debate, conducting and presenting a group research project, or working to co-author a research report. It is usually implemented with the help of specific facilities. For instance, if the task is to co-author a research report, then such facilities should be used: it collects student's contributions and combines them into a research report of the whole group by avoiding the possible conflicts between student's private versions and the group's version of the research report.

From the above analysis of the learning procedure in the CSCL, it can be seen easily that there are a number of challenges for students to tackle in each stage of the CL. If the effective assistance and support can not be provided in these stages, they will have problems in addressing such challenges.

The CL process supported by the agents – current situation

Our current research is based on a workspace system, *LiveNet*, which enables us to compose learning spaces. So far this has been use to distribute materials, manage discussions, and support students to setup their own workspaces (Hawryszkiewycz, 2003). Recently we have extended it to support group management processes. The paper will first briefly provide an overview of the collaborative model used in LiveNet system, which underlies the implementation of our agent architecture. Then it will describe the way agents can facilitate group work.

The collaborative model used in LiveNet

LiveNet system is a research prototype of knowledge management and enterprise collaboration, developed by our research group. It has been successfully applied into a number of domains including project research and subject teaching. LiveNet is implemented as a Web based three-tier system. Students interact with a LiveNet client via a Web browser, which communicates with a LiveNet server by the HTTP protocol. The server in turn interacts with a relational database management system in whose databases the workspaces, and their elements, and related items are stored. LiveNet implements the interactions between clients and a server by using JPS technology and it thus allows any students over the Internet to join the CL through their Web browser.

LiveNet utilizes workspaces as the commonly shared places for online students to conduct CL. It provides the flexibility to set up workspaces and supports their dynamic modification and evolution. The elements which define the workspaces in LiveNet include: roles, actions, artifacts, messages and message types, etc. The relationship between these elements is expressed in a meta-model shown in Figure 1. More detailed about LiveNet can be found in http://livenet4.it.uts.edu.au/index.jsp.

In the following we will integrate software agents into LiveNet to actively help and guide the participating students to better make use of the workspaces for CL.

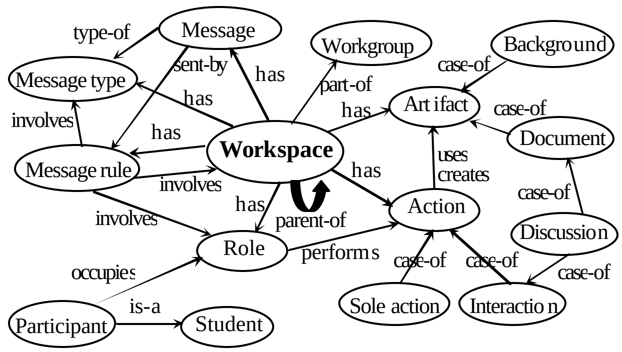

Fig. 1. The meta-model of the workspaces in LiveNet

A multi-agent architecture to facilitate group work

An example of a multi-agent architecture for a simple case is shown in Figure 2 illustrates the agents identified and the multi-agent structure for the case study system. Here there is a case study agent and a case study task agent. The case study follows a plan that includes the completion of a number case study tas ks. The plan is currently defined by the instructor. The case study agent delegates work to tasks by creating a workspace with its own case study task agent for each case study task of the plan. The case study task agent monitors progress on the task and reports to the case study agent. A supporting activity to analyze situations faced in each test is created for each task. The interactions between the agents can be shown using sequence diagrams.

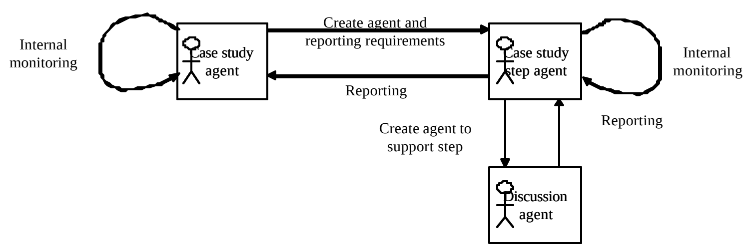

Fig. 2. case study agents

Generic criteria for Defining Agents

In defining the generic agent structures the basic strategy is to define good characteristics of collaboration and set these as agent goals . The agents observe the environment in terms of metamodel concepts and take actions in the same terms to improve the process if necessary. The agents must then observe system behavior and send out notifications and suggestions to participants. Such requirements and observations must be expressed in terms of the metamodel concepts. As an example, typical good characteristics for work-item agents include:

1. Responsibilities are properly assigned by ensuring that team members with the right expertise are assigned to relevant roles.
2. Work is proceeding in a steady manner by tracking changes to output documents,
3. There is interaction between team members. To do this, the agent observes contributions to discussions.
4. Information is well organized by ensuring all the documents are included in the workspace context .
5. Decisions are being made as evidenced by changes to output documents.
6. Correct knowledge captured to ensure product quality by ensuring all documents related to the goal.

There are also characteristics that require further input from members such as their opinions on whether deadlines can be met, whether the output is of good quality and that everyone is aware of the output and associated issues.

Good characteristics for activity agents include:

1. Is the process well organized with role assignments and people assigned to roles?
2. Work is delegated to work-item agents
3. Work-items are scheduled according to plan and monitored to determine possible delays.

Agents then observe the collaborative environment and take actions such as rearranging activities, reminding team members to carry out tasks, setting up support activities and initiating new activities.

Continuing the example

The process produces outputs at predefined stages. The outputs in our example are:

Output artifact in 1 – case study plan to assist management,
Output artifact in 2 – the output of the task (impact table, etc.),
Output artifact in 3 – a discussion about the issue.

At a more detailed level, we use the usual reasoning model of agents shown in Figure 3 that shows the agent components and the relationships between them. Here a goal leads to a plan, which is defined in terms of rules that lead to actions. The plan itself can have lower level goals. The reasoning model is implemented using the three layer architecture (Müller, 1996) chosen from a number of alternative architectures (Wooldridge, 1999). Agents are used to achieve goals using plans defined by agent users. A plan is composed of event-condition-action rules, each of which specifies the actions to be executed when condition is true. When choosing a plan for a goal or asserting a condition in rule, beliefs are employed.

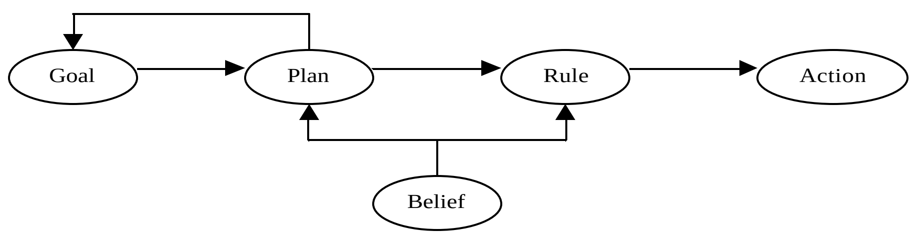

Fig. 3. The agent reasoning model

We can predefine the goal, belief, plan, rule, and action for an agent or define them at run time.

The definition is generic as the output documents can be chosen for a particular process as can be the various times and roles.

Future developments

Our proposal is to extend the system with additional agents that raise awareness and improve the partitioning of tasks between group members. One extension is to add personal, PrAgent, and group agents, GrAgent. One example is a personal assistant, PerAgent, which will assist students to accomplish their learning tasks. These will include:

- raising awareness of all the participating students in different collaborative groups currently existing in the system. This information can be obtained by the PerAgent through a set of database queries. The relational database stores the information of all the workspaces in the system, including the names of participators in each workspace.
- following criteria for the composition of a CL group. One aspect is the size of a group. The PerAgent can easily calculate the total number of participators in each workspace by database queries and hence finds groups with appropriate size. Another aspect is the learning characteristics of the students in a

CL group should satisfy some conditions based on the theories of CL. Every student in the system has a profile stored in the database and it is built while he registers in the system and updated during he studies in a CL group. The profile contains the learning characteristics, including background, preference, styles, etc. The GrAgent for a CL group stores the common learning characteristics of the students in the group. Thus the PerAgent communicates with each of the GrAgents to seek for a match between the student and a CL group by comparing the learning characteristics. While a match is found in the compassion, the corresponding CL group is an appropriate one.

- negotiation with the group which the PerAgent has found appropriate for the student to join. It is natural that it needs to get approval by the group if a student wants to join a group for CL. It is the duty of a GrAgent to decide if a new student can be accepted to join into the group. Thus the PerAgent negotiates with the GrAgent and tries to get its approval.

After a candidate group is achieved, the PerAgent may recommend the group for the student to consider, or directly put the student into the group without asking him, depending on the designated threshold. The PerAgent then interacts with the GrAgent for the group the student will join to accomplish the registration for the student.

The partition of the learning task

The overall learning task for a CL group is divided into several sub-tasks for each of the students in the group to perform individually. The GrAgent for a CL group is responsible for the work in cooperation with all the PerAgents in the group.

Because there is no particular rules to follow for the work due to the complexity involved, this work is implemented based on the distinguished characteristics of software agents; they can learn by observations. For each task partition, GrAgent records the task type, the adopted learning modality, the learning style of each student and their respective sub-task, etc. for the future reference. When GrAgent is asked to partition and allocate a new task, it searches in its *parameter base* to find a partition which is most approximated the current one. Then GrAgent uses this as a *preliminary* plan of partition and negotiates with all the PerAgents of the group in attempting to carry out the plan. If the plan can be implemented, the rank of the partition will be increased in the *parameter base*. Otherwise, necessary changes for the plan are made based on the negotiation and a new partition record will be appended to the *parameter base*.

Several ontologies for specifications of a set of conceptualization which defines the terms, relations, functions, etc. are used here to construct the message semantics in communication between agents (Cheikes, 1995).

Individual learning

While the student performs the learning task assigned to him, the PerAgent for the student monitors his actions, proactively offers him various assistances. PerAgent can provide the student with many kinds of personalized assistance in this process by the coordinated efforts with other agents. For instance, it can search desired course material over the Internet, it can reply email messages pertaining to course topic discussion on behalf of the student, and it can offer suggestion on the person and place to get help for the learning. The relevant work and the implementation details have been reported in (Pan, 2004). During this process, the PerAgent also updates the student's profile if the necessary is monitored.

The combination of the learning achievements

This is undertaken by an autonomous agent. Such an autonomous agent acts independently based on the requirement of a concrete learning task and it simply performs the designed task and then terminates. The implementation of the agent depends on the type of the learning task at hand because the way of combining learning achievements of individual students is determined by the type of the learning task. One agent is employed for a specific type of the learning tasks in our implementation. As an example, the agent for the task working to co-author a research report in turn gives the control to an individual student based on some rules to let him copy his own private version into the overall version of the whole group.

Conclusions and outlooks

Collaboration is emerging as one of the promising learning paradigms in *e*-learning over the Internet. Despite the complexity involved in the development of CL systems, more research efforts should be spent in the exploration of the paradigms to better support and facilitate students learn over the Internet. This paper utilizes software agent technology to actively help and guide students in the CL processes, e.g. composition of a CL group, partition and allocation of a learning task, individual learning and the combination of learning achievements. Preliminary research has revealed that the software agents are able to facilitate the CL and result in some positive outcomes.

The architecture of agents presented in this paper is not limited to the LiveNet system. Any CSCL system which uses workspaces as the shared place for collaboration can be integrated with the architecture in a similar manner.

Based on the experience of this research, we will extend the collaboration facilitated by software agent technology in both the scope and depth so that it can be employed to improve the learning over the Internet.

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