FACILITATING COLLABORATION AMONG STUDENTS IN E-LEARNING BY SOFTWARE AGENTS

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ABSTRACT

Computer supported collaborative learning (CSCL) is one promising technical means to facilitate *e*-learning over the Internet. However, most current CSCL systems do not *actively* provide support for collaborative learning (CL). In such systems, students get little assistance from system for the CL activities, e.g. the formation of a CL group, the partition of a learning task, the combination of learning outcomes, etc. This paper seeks to *actively* assist and guide students to conduct CL by using software agents. The challenges that students are confronted with in CL over the Internet are investigated at first. Based on the challenges, a multi-agent architecture to facilitate CL is proposed. Then, the implementation on one particular CSCL system, *LiveNet*, is presented and the agent services to support CL are explored.

KEYWORDS

Collaborative learning, software agent, Computer supported collaborative learning, learning group, learning task

1. INTRODUCTION

Computer supported collaborative learning (CSCL) is one of the most significantly technical means to facilitate e-learning. Collaborative learning (CL) is referred to a variety of learning activities that seek to promote learning through collaborative efforts among students in groups. It provides an opportunity to share and exchange ideas and views among students with common learning interests. CL has many attracting merits such as it brings higher motivation to engage in learning task, deeper understanding of content, improved self-esteem, and promoted teamwork skills. CSCL delivers a virtual collaborative environment by using information and communication technology where students can take part in CL over the Internet.

Currently most CSCL systems only deliver electronic learning spaces for CL with little or no consideration to actively provide supportive services for participating students to conduct CL. These systems in fact leave students to conduct CL by their own efforts. Students get little assistance from system for their CL activities, more specifically, the formation of a CL group, the partition of a learning task, the combination of learning outcomes, and their individual learning, etc.

This paper proposes a way to facilitate CL over the Internet by software agents. Software agents are incorporated with a CSCL system to assist participating students to conduct various CL activities. They, by their coordinated efforts, actively assist students to get through a CL process. The paper is organized as follows. The challenges in CL over the Internet are investigated in Section 2. An overall architecture of a multi-agent system to assist students to tackle the challenges is proposed in Section 3. The implementation of the architecture under a CSCL system is presented in Section 4. Finally, Section 5 is a summary of the paper.

2. CHALLENGES IN CL OVER THE INTERNET

Students are faced with a number of challenges when they participate in CL through the Internet. Here the challenges are briefly analyzed through examining a CL process over the Internet. A process of CL conducted over the Internet can be structured into the following four sequential stages:

- Formation of a CL group. Although it may be easy in a face-to-face CL environment to find appropriate fellow students to study together, it is very hard when CL is over the Internet because online students are geographically separated over the world. They probably do not know about other students who have similar learning interests. They may have different cultural backgrounds.
- Partition of the learning task. In CL, the learning task for a group needs to be split into several sub-tasks and allocated to individual students in the group. Because students over the Internet mostly do not know each other in terms of learning styles, it is difficult to partition a learning task in a way that all of the participating students could benefit to a maximum degree in accomplishing the assigned task. Moreover, it becomes even more difficult while the task is complex or for solving an ill-defined problem in a knowledge domain (Suh, 2004).
- Individual learning. In CL, the cooperation and individual learning are complementary modes of learning (Shaw 2005), and the individual learning is a basis for the cooperation. When CL is over the Internet, an individual student studies in his or her own workstation and the learning activities are usually Internet-based. In such alone learning, the student has to, by his/her own efforts, decide what, when and how to learn for the allocated task. Some students may have problems to independently make such decisions.
- Combination of the learning outcomes. Because individual students in a group study for a common goal, their learning achievements should contribute to the overall learning outcomes of the entire group. It is very hard to collect the learning outcomes achieved respectively by each individual student in the group, especially when the learning task is complex or for solving an ill-defined problem.

3. AGENT-BASED APPROACH TO FACILITATING CL

3.1 Overall Architecture of the Agent-Based CSCL System

In order to assist students to tackle the challenges described in the previous section, software agents are incorporated into the CSCL environment to provide relevant supportive services. Fig. 1 illustrates the overall architectural framework of the system. Students interact with electronic learning spaces to collaboratively manipulate the problem under study, build their own knowledge representations, and communicate with one another to share and exchange ideas and views. Software agents are linked to the learning spaces through events and actions. They, independently of students, observe and monitor the change in the learning spaces. They take events in the learning spaces as input and provide actions to the learning spaces as output aimed to facilitate and support CL. The database that contains the description of the current collaborative activities provides some of the necessary information for agents to realize the supportive services.

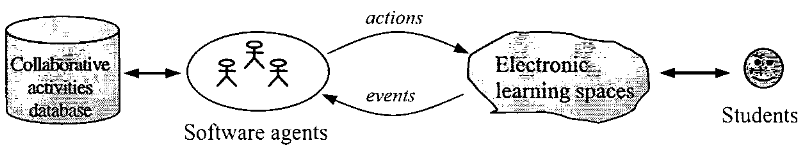

Figure 1.Overall architecture of the agent-based CSCL system

3.2 The Multi-Agent Architecture

The multi-agent architecture contains a number of agents with different expertise. They work together to assist students to collaboratively accomplish learning tasks. A software agent in the architecture is as defined an active, persistent software component, situated in the CL environment, that is capable of interacting with other agents to solve dependencies between them and taking autonomous and rational actions to assist students to take part in CL activities (Jennings, 2000). An agent is built with one or more such actions and a decision and reasoning mechanism that decides when it should execute an action and which action it should execute. The mechanism in our agents is fulfilled using a well-known BDI architecture (Wooldridge, 2002).

Two major categories of agents in the architecture are described as follows:

- Student assistant agents are for individual students. Each student is assigned with an agent, which we call StuAgent, while the student logs into the system for learning. It acts as a personal assistant for the student it has been associated with. Its duty is to support and manage the learning activities taken by the student. The agent maintains a profile for the student to store his/her learning characteristics and the information about the learning progress of the student, including the previous learning experiences, advancement, etc. The agent updates the profile as the learning proceeds, and provides the related information to other agents when being requested. In addition, the agent is responsible for negotiating with the agent for the group that the student belongs to for task allocations.
- Group agents are for CL groups. Each CL group is endowed with an agent, which we call GrAgent. Its main task is concentrated on facilitating the learning by the entire group. A GrAgent, on behalf of a group of students, is responsible for the management of the group members. It is also responsible for assisting member students in task partitions and allocations according to their individual characteristics of learning. For successful completion of these duties, it maintains the information of the CL group, e.g. its member students, their learning characteristics in common, learning progress for the current task, etc.

4. CL PROCESS SUPPORTED BY SOFTWARE AGENTS

The research is currently under implementation on a CSCL system, LiveNet (http://livenet4.it.uts.edu.au). In this section, the approach that software agents facilitate CL under LiveNet is explored. Before doing so, an overview of the collaborative model used in LiveNet is briefly described, which underlies the approach.

4.1 Collaborative Model Used in Livenet

The LiveNet system is a research prototype of knowledge management and enterprise collaboration, developed by our research group. It supports both synchronous and asynchronous collaboration of distributed groups of people. It has been successfully applied into a number of domains including project research and subject teaching (Hawryszkiewycz, 2005).

LiveNet utilizes electronic learning spaces as the commonly shared place for online students to conduct CL. It provides the flexibility to set up learning spaces and support their dynamic modification. The elements that define a learning space in LiveNet include roles, actions, artifacts, messages and message types, etc. (Hawryszkiewycz, 2005). A learning space includes a collection of the elements and their relationships, methods to operate on the elements and relationships, and relationships with other learning spaces. Students can, based on their learning requirements, set up learning spaces, which may be within an existed learning space. This forms a learning space tree with hierarchical architecture. The learning space tree represents, stores, and maintains the dynamics of collaborative learning in LiveNet. The learning space tree is managed through a relational database management system.

4.2 Formation of a CL Group

In general, a student may determine partners to study together through two ways. One is to build a new CL group, his or her own group, with some appropriate students; and the other is to join an already existed CL group. Obviously, using either way the student needs information about the learners currently in the system. The StuAgent that has been associated with the student assists him/her to determine partners major through providing him/her with the required information. The assistance mainly includes:

- Providing the information about the learners who have the same goals and similar learning styles with the student (Miettinen et al., 2005). The StuAgent first finds the learners who are studying the same topic with its owner student and then further determines the ones who have similar learning styles with its owner. A learning space in LiveNet is a place for learners to study a particular theme and exchange ideas and views for the theme. Hence, the learners who are studying the same topic with the student are in fact the participants of the current learning space that the student is in. Since the collaborative activities database in the LiveNet system stores the information of all the learning spaces in the system, including the names of participators in each learning space, the StuAgent can obtain the information about the students who are studying the same topic with its owner through a set of database queries. Then, from these learners, the StuAgent selects the ones who have similar learning styles with its owner. Because each StuAgent maintains a profile for its owner which contains the information relevant to learning styles, the StuAgent can contact each of the StuAgents to get its owner's learning styles and compare with the learning styles of its owner student to seek for the matched ones.

- Recommending groups for the student to join based on some principles. Two principles are adopted for formation of a CL group in our implementation. One is the rule for the size of a group, i.e. the number of students in a CL group is restricted within an appropriate range (Suh, 2004). The StuAgent can attain the total number of participators in each learning space by database queries, and hence finds a group with an appropriate size. Another principle is the students in a CL group should have common learning characteristics to a certain extent. Every StuAgent maintains a profile for its owner student which contains his/her learning characteristics, including background, preferences, styles, etc. The GrAgent for a CL group stores the common learning characteristics of the students in the group. Thus the StuAgent interacts 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 considered as an appropriate one for its owner student to join.
- Arranging liaison with the fellow learners whom the student will study together. It is natural that if a student wants to join a CL group to study together with the group members, he or she needs to get approval by the group. Alternatively the student also needs to contact the learners if he/she wants to invite them to build a new group for CL. The StuAgent advises the student of the email address and other contact information for him/her to contact them. It also arranges the liaison if he or she decides to contact them.
- Performing some activities related to formation of a CL group. If the student builds a new CL group, the StuAgent will create a learning space for the group. If the student joins into an already-existed CL group, the StuAgent will on behalf of him/her perform some related registration for the group.

4.3 Partition of a Learning Task

The overall learning task for a CL group is divided into several sub-tasks for the member students in the group to perform individually. The GrAgent for a CL group in cooperation with all the StuAgents in the group assist the member students in the group to implement the task partition and sub-task allocation.

There is no all encompassing rule to follow for splitting a learning task. The choice will be made based on a variety of factors. Basically a learning task partition depends on the task types, the learning modality being adopted, the participating students, their cognitive abilities and learning characteristics, and so on. It is very complex to split a learning task and allocate the sub-tasks to the participating students in ways that all of them could be benefited from the accomplishing of the assigned sub-task. In our implementation, initial partition schemes for a group task are designed by experienced teachers and recommended to the member students. Due to the complexity involved, a partition scheme currently is a list of all the sub-tasks and the requirements for the students to undertake a sub-task in terms of learning characteristics. More sophisticated partition schemes are under research. The intention behind is to initiate the task partition and sub-task allocation and facilitate their completion.

The GrAgent first suggests the initial partition scheme by putting it into the learning space as a preliminary plan to split the learning task for the entire group. It then negotiates with all the StuAgents in the group to try to allocate all the sub-tasks. It sends each StuAgent in the group a request for undertaking a sub-task based on the preliminary plan. The students in the group can freely select sub-tasks that they are willing to undertake. They are encouraged to undertake more sub-tasks. If a confirmation of accepting the request is returned from a StuAgent, the sub-task will be allocated to its owner student. If there is a sub-task no student likes to undertake, further appeals are followed; a request for undertaking the unallocated ones will be sent to the group members, especially the students who have only consented to undertake less work. In our implementation it is allowed that more than one student undertakes a same sub-task, and a student undertakes more than one sub-task. This is to ensure that any of the sub-tasks has at least one student to undertake.

4.4 Individual Learning

While a student performs the assigned learning tasks, the StuAgent for the student monitors and evaluates his or her behaviors in learning, actively offers various assistances for him/her to facilitate effective knowledge construction. This is implemented through the coordinated efforts of the StuAgent and other agents in the system. These agents assist the student to build knowledge not through understanding the academic content of the study themes, but rather through providing a wide range of services that are useful for students to get through a learning process (Pan and Hawryszkiewycz, 2006). These services include: 1) providing appropriate learning resources for the topic the student is studying; 2) guiding and helping him/her to develop personalized preferred learning plans that satisfy his/her learning needs and match to his/her unique learning charcateristics; 3) assisting him/her to timely align learning according to the practical progress of his/her learning and 4) advising him/her of discussion forums to participate in discussions on the study themes. The purpose of such kind of services is to engage the student in knowledge construction and promote the active learning through providing guidance for him/her to solve the problems which he/she often meets during individual learning.

4.5 Combination of the Learning Achievements

The combination of the learning achievements is undertaken by an autonomous agent (Wooldridge, 2002). 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 hands 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. Currently we have only experienced with structured learning task; the task is divided into several parts. Thus the combination of the learning achievements is to collect the outputs of all the sub-tasks and put them together.

5. SUMMARY

This paper utilizes software agents to actively assist and guide students in a CL process, e.g. the formation of a CL group, the partition and allocation of a learning task, individual learning, and the combination of learning achievements. Preliminary research has revealed that agents are able to facilitate CL and result in positive outcomes. Further investigation is under way.

The architecture of agents presented in this paper is not limited to the LiveNet system. Any CSCL system that uses electronic learning spaces as the commonly shared place for collaborative learning can be integrated with the architecture in a similar manner.

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