Supporting Collaborative Learning in Virtual Worlds by Intelligent Pedagogical Agents: Approach and Perspectives

Mohamed Soliman

IICM, Graz University of Technology, Graz, Austria
muhamed.soliman@gmail.com

Abstract. Intelligent pedagogical agents (IPA) are aimed to support learning in virtual worlds. Motivations for adopting IPAs in virtual worlds are to compensate for lack of human pedagogical presence, to improve student engagement, and having autonomous support. Given named challenges to realizing IPAs in virtual worlds, a proposed solution approach is to simulate IPAs with targeted scenarios with intelligent agents prior to realization. This paper discusses intelligent agent based simulation of a collaborative learning scenario that facilitates IPA support to collaborative learning in virtual world. The collaborative learning scenario is composed of multiple avatars interacting to conduct an experiment simulation in a virtual world with an IPA. The paper discusses types of support the agent will do to scaffold the interactive collaborative learning activity, for example by mediating interaction among learners and targeting learning to collaborate as well as collaborating to learn with benefits shown.

Keywords: CSCL, Intelligent Pedagogical Agents, Intelligent Agents

1 Requirements

A collaborative learning activity design is motivated by the objective to employ Intelligent Pedagogical Agents (IPAs) in virtual worlds to support learning. While there are different means to support collaborative learning in virtual worlds (Dalgarno, 2010), automated and artificially intelligent pedagogical support are still needed. Design objectives of IPAs are to provide automated and intelligent pedagogical support while improving engagement throughout interactivity. While there are different roles the IPA can do to support collaborative learning activities in a virtual world, there is the importance of focusing on interaction among learners and with a leaning object in relation to situated learning and learning by doing. Prior works (Soliman & Guetl, 2010; Soliman & Guetl, 2013) highlighted other possibilities of IPA support.

In contrary to an individual learning scenario, the IPA role has to shift towards being more of a mediator that facilitates the dialogue and interaction among the learners and the learning object in the collaborative setting. An important task of the IPA is to maintain distribution of roles, as a key component, among different learners (Hoadley, 2010). Distribution of roles in the task is assumed to be available as an input to the learning activity. The IPA is assumed to be executing a micro level script rather than a macro level to discover details of interaction as a design objective (Kollar, Fischer, & Hesse, 2006; Weinberger, 2011). Selection of the group size is determined to start with two learners agreeing to what is cited by Hoadley (2010), *"Stahl (2006) has argued that the small group level is the 'sweet spot' for studying CSCL"*.

The targeted scenario is described by two avatars performing an experiment simulation with the aid of an IPA. The avatars are human controlled while the IPA is an autonomous agent. The IPA supports the learning activity with the following:

1. Provide tutorial about the experiment. In collaborative learning scenarios, the IPA will intervene only to scaffold learning after giving the opportunity to other learners to learn to collaborate.
2. Providing motivational support.
3. Answer questions. In the group learning, the IPA will rather stimulate group interaction before answering a question individually.
4. Support the collaborative activity such as "who is supposed to perform this task?"
5. Promote reflection and trans-activity (Boud, Keogh, & Walker, 1985) as important components to collaborative experiential learning.
6. Provide varying levels of support from the learner level to the group level.
7. Ensure continuation of the activity, to manage idle time behavior for example.

However, several challenges exist for implementing an IPA directly into the virtual world, Soliman and Guetl (2013). Hence, simulating the collaborative learning activity in the intelligent agent framework is useful. This is to focus on interactivity and intelligence support to the collaborative learning activity and to identify how an intelligent agent can complement the IPA functions in particular to the collaborative interaction.

2 Solution Approach

2.1 BDI-Based Collaborative Learning Scenario Simulation

The BDI agent framework of Jadex (Jadex, 2013) is adopted as a result of evaluation and selection steps (Soliman & Guetl, 2012). Inter-agent communication is used to simulate the players' interaction in the learning activity communication towards enabling its analysis and reasoning. In BDI based environments, multi-agent design involves determination of goals, plans, events (or messages), and beliefs. Goals represent static or dynamic desires the agent should pursue, plans represent intentions (as recopies of the solution) translating into actions. Beliefs represent agent knowledge about the environment and other learners and can also change dynamically according to events. A BDI based collaborative learning scenario simulation involves determination of goals, plans, and beliefs.

2.2 Settings and Design

Setting the experiment implies simulating the players (actors and artifacts) of the scenario in the virtual world. Four agents are defined: an agent representing the IPA, two agents representing the learner avatars, and an agent that simulates the intelligent object (device) behavior in the virtual world. The BDI-based agent design requires setting the beliefs, desires, and intentions of the agents:

- *The IPA agent* has beliefs about learners, the task, and the roles. The desire of the IPA is a pedagogical goal to facilitate (direct) the completion of activity. The intentions of the IPA are plans representing variations according to interactions.
- *The device agent* represents an experiment. It gives an autonomous behavior property to the object to simulate different results that can be handled in learning settings by learners or the IPA.
- *Two learner agents* are allocated. The desire of each learner agent is to accomplish the learning experiment in collaboration with another learner. Intentions adopt sequences in results to interaction. Beliefs add details of the learner knowledge about the other learner.

2.3 Interaction & Collaboration

The IPA initiates the first step to run the experiment and finds, in the role-responsibility beliefs, which learner is allocated issuing a request for the assigned learner agent to start. If the correct action is performed, it updates the assessment belief base. If the task is wrong, as observed from the device, the IPA records and triggers collaborative discussion with the other learner. The task is repeated (according to pre-set number of trials) by the same learner (if a capable learner can show the task, it can be performed by another learner). Otherwise, the IPA can give a demonstration of how the task if performed and move to the next task. The IPA will continuously monitor the interaction identifying which agent is responding. Consecutive tasks will proceed until the experiment completes. Before each step, IPA sends a message to both learners to trigger discussion on how to perform the next task. In each step, if the wrong learner responds, IPA issues an error message while recording the result into the assessment belief set. Directing messages to both learner agents serves the learning to collaborate objective. Furthermore, when the IPA recognizes long idle time, it asks both learners to discuss roles and the expected task on which action to take.

3 Concluding Remarks

The learning scenario is implemented in Jadex as a selected agent platform to avoid difficulties of actual implementation. The simulation of this scenario in the agent based environment helps to:

1. Isolate implementation difficulties in a virtual world.

2. Discover means of IPA support for collaborative scenario – how the collaboration scenarios will take place in a virtual world implementation.
3. Discover means of interaction design for the learning scenario in relation to roles.
4. Requirements from the learning object to support the learning interaction from one learner in relation to more than one learner.
5. Investigations into integrating micro-level collaborative scripts and contributing a collaborative pattern of IPA in virtual world based learning.

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