An Approach for Integrating 3D Virtual Worlds with Multiagent Systems

Jeanne Blair
School of Computing and Information Systems
Athabasca University
Banff, Alberta, Canada
Jeanne.blair@telus.net

Fuhua Lin
School of Computing and Information Systems
Athabasca University
Athabasca, Canada
oscarl@athabascau.ca

Abstract— Education is incorporating more and more of the capabilities provided by the Internet. One such move is the incorporation of 3D virtual worlds in the learning environment. Another is the increasing development of multiagent systems that support the learner or the tutor. Integrating pedagogically based multiagent systems with 3D virtual worlds could provide a more engaging immersive learning environment. This paper explores the feasibility of integrating a 3D virtual world with a pedagogical multiagent system named QuizMASter, an educational game for elearning that helps students learn their course material through friendly competition. The integration was developed by devising, implementing and testing an approach using open source technologies, namely, Open Wonderland and JADE. The result is encouraging as the integration is technically feasible, not overly difficult and opens a door to further integration opportunities.

Keywords-component; Education, Multi User Virtual Environment, 3D Virtual Worlds, Multiagent Systems

I. INTRODUCTION

A. *3D Virtual Worlds as Learning Environments*

Learning environments that provide an immersion into the content is a natural step towards creating learning environments for the new “digital native” group of learners [1]. The current generation of learners are used to multimedia applications that are immersive and highly interactive because many of them have been video-gaming since they were kids [2]. Multi user virtual environments (MUVE) have been created by many of the world’s universities to provide such a learning environment in a 3D virtual world. A MUVE is best used by a synchronous but geographically separated group of learners [3]. MUVEs are said to be perfect for “experiential” learning by providing concrete experience, reflective observation, abstract conceptualization, and active experimentation [4].

Two different approaches toward MUVE’s are surfacing; the virtual classroom and the fantasy world. The virtual classroom has the look and feel of a regular classroom and is often made to look like a replica of the sponsoring university. Second Life (SL) is often the choice for building the 3D virtual classroom [3-5]. Results are a mixed bag, with some reporting that SL has too many difficulties and is not game like [4]. Some learners reported that SL is not an environment where they would want to spend time [6]. SL did not appeal to those who enjoy social software because of difficulties engaging with others, nor did it appeal to gamers because of the lack of any gaming scenarios.

The fantasy world teleports the learner to a different place or time. Virtual Singapura [7], an example of a fantasy world, takes the learner to nineteenth century Singapore in the throes of a disease epidemic. Here, faced with the daunting task of being limited to only the technologies of the time, the students have to solve the problems of the time. Their guided activities are based on the Virtual Singapore Lab Book, leading the student in the use of scientific inquiry skills and science content about communicable diseases. Another example of a fantasy world MUVE is Mare-Monstrum where the tutor takes the form of a dragon and learners face challenges and collaborate at a cliff [2]. Fantasy worlds offer the ability to construct learning environments that use Problem Based Learning (PBL) as the underlying pedagogical strategy [2]. Fantasy MUVEs offer socio-constructive pedagogy via PBL collaborations where the tutor role changes from being the “sage on the stage” to being a guide in the process of finding a solution to a problem [8]. Using such a MUVE, the Electrical Engineering School at the University of Madrid reported a decline in drop-out rates in engineering education due to the incorporation of virtual world games [2]. A study of World-of-Warcraft, arguably the most popular 3D virtual world, led researchers to define a reward model of four reward groups, glory, sustenance, access and facility that would be transferable to an educational 3D virtual world [9].

Layering problem based learning, rich reward models, collaboration and fantasy 3D worlds offer pedagogic values by immersing the learner into a world for an interactive, engaging and fun encounter that encourages active learning and motivates participation [10].

B. Multiagent Systems that Support the Learning Environment

Agents are encapsulated computer systems that are designed to behave flexibly and somewhat autonomously to achieve some goal(s) [11]. Agents are situated in some environment and have some autonomy and capabilities to observe that environment. They can communicate those observations to other agents. This makes them particularly suited to distributed environments. Within the distributed environment, the Multi-Agent System (MAS) can be designed using one or more architectures. The autonomous nature of agents implies that the architecture can even develop dynamically at run-time. A group of peer-to-peer agents can appoint one agent to be a central agent to whom the others report.

The application of multiagent technology to education has fallen into two groups of technologies, 1) Intelligent Tutoring Systems (ITS) and 2) Interactive Learning Environments (ILE) [12]. Some criticism of the current state of tutoring systems is the lack of sufficient intelligence in the tutoring system with a possible solution identified as the incorporation of pedagogical multiagent systems, such as a teacher agent and a student agent into the virtual classroom [12-14]. Multiagent systems can also provide agents that act as guides, information retrieval assistants, and help systems in 3D virtual learning environments [15-18]. The pedagogical benefits provided by the interactive MAS in learning environments are shown to be [10]: Interactive learning experience motivates students and helps to retain knowledge, instant feedback helps identify weakness in areas, interaction with other students introduces the competitive element which in turn makes the experience more engaging, interesting and fun, students collaborate with each other and students progress at their own pace

C. Rational for this research

An immersive game-based learning environment is typically a dynamic three-dimensional (3D) "learning space" that is constituted by the context, the user, the content, the learning objects, and the learning activities. We are proposing a framework for such environments through incorporating the adaptivity, collaboration, and intelligence features into the environments to enhance the usefulness and usability. The framework will integrate a game-based multiagent system into a 3D virtual world. A variety of technical challenges, such as differences in concern between multiagent technology and 3D virtual world technology with regard to interoperability, communication, and level of autonomy, and the pedagogical challenges such as learning strategies, successful factors in promoting learning, learning activities design, learning preferences/styles modeling, needs to be addressed.

We aim to address these issues through selecting a multiagent platform, JADE, and the game engine Open Wonderland. We use multiagent technology to maintain user models and interactive learning activity elements, which allows us to incorporate intelligence and adaptivity features into the game adding to the overall fantasy of educational games. An important outcome of our research is to identify a suitable mechanism for the exchange of learning activity information between the Open Wonderland 3D environment and the JADE multiagent system. We propose a messaging system in which 'percept' messages are sent from Open Wonderland to the MAS, and 'action' messages are sent from the MAS to the Open Wonderland environment. Using this approach, the MAS system could detect and react to important game events in the WL environment. In order to test and verify our approach, we are implementing a prototype multiplayer educational game based on a TV game-show theme.

The remainder of this paper is structured as follows: Section II provides a brief description of related work. Section III defines the methodology used in this research. Section IV lays out the architecture of the solution. Section V describes the implementation of this research work. Section VI presents the results of this research and Section VII the conclusion and planned future work.

II. Related Work

Other research into the integration of 3D virtual worlds with multiagent systems is limited to just a few examples. The best known is GameBots developed at the University of Southern California in collaboration with Carnegie Mellon University, which integrated agents into a 3D virtual game environment called Unreal Tournament [19]. More recently, the University of Lisbon developed e-Game, which is an integration of a JADE multiagent platform with a video game environment called Counter-Strike [20]. The University of Le Havre developed an Intelligent Tutoring Systems, also built as a JADE multiagent system that is integrated with a 3D virtual world based on SCOL [21].

III. Methodology

A survey of the research presented above led to a realization that multiagent systems could enhance the educational aspect of a 3D world such as Open Wonderland. The challenge is to find an approach for integrating multiagent systems with Open Wonderland that is not overly difficult and does not require drastic changes to either the 3D virtual world or the multiagent software. The benefit of such an approach is that multiagent systems could be incorporated into 3D virtual worlds to provide real world information or services, such as information retrieval, or provide adaptive learning based on learner styles. Building such features directly into Open Wonderland would require a knowledge of complex programming. The sheer complexity of implementing an educational game in a 3D virtual world presents the most significant barrier to widespread educational use. For example, jMonkeyEngine (JME), the engine on which Open Wonderland is based, is a powerful game-engine that provides the low-level infrastructure needed to build 3D graphics systems and games. The JME provides functionality for rendering, collision detection, and other core functionalities required to create a 3D virtual world. It could be therefore argued that the JME provides all the necessary tools to construct an educational game. However, the JME game engine is all but inaccessible to most educators. To implement an educational activity using the JME as a starting point would be impossible for anyone lacking advanced computer programming skills, and a significant amount of time to devote to its implementation. Open Wonderland takes an important step towards making 3D virtual world technology more accessible to non-programmers. The Open Wonderland toolkit builds upon the JME infrastructure, adding features that enable the content developer to more easily add virtual world elements such as buildings, furniture, scenery, and other elements needed to provide an immersive 3D experience. For example, educators will benefit greatly from Open Wonderland's ability to import graphics elements from Google's 3D Warehouse, which contains thousands of 3D elements in a wide range of categories, and are available free of charge. The toolkit also provides support for adding items such as whiteboards, PDF viewers, and other components useful for educational applications. Perhaps most importantly, the Open Wonderland toolkit provides the user with an avatar through which s/he interacts with the 3Dvirtual world.

Our approach to this challenge was to find a way to integrate a multiagent system developed on the Java Agent DEvelopment framework (JADE) (jade.tilab.com) with Open Wonderland (OWL), an open source 3D virtual world developed by SUN (www.openwonderland.org). JADE is the best-known and most widely used platform that supports FIPA (the Foundation for Intelligent Physical Agents*)* messaging [22].

Open Wonderland is a 100% Java open source toolkit for creating collaborative 3D virtual worlds. JADE is also a 100% Java open source toolkit. Since both JADE and Open Wonderland are Java toolkits, integrating these two technologies would not suffer from problems of cross-platform issues, thus they were selected for this applied research.

JADE agents are implemented as Java threads. One important principle in JADE is that communication is transparent, in the sense that the programmer needs not be aware of the mechanism used to actually deliver messages. Communication is handled by the JADE run-time environment.

During a comprehensive review of these technologies we discovered that JADE provides a method to start a JADE agent from a third party application and we felt that it should be possible for Open Wonderland to be that third party application. A careful study of the JADE InProcess example provided the "aha" moment as it became clear that it would be possible to start a JADE agent inside the Open Wonderland world by simply using the Jade provided methods in the `jade.core.Runtime` package. Thus the idea formed for modifying the SAMPLE module to start a JADE agent and have the agent send pertinent information back to Open Wonderland in the form of messages to a TCP port. Open Wonderland scripting provides a powerful method for animating modules without changing any source code and this feature was identified as the means of adding TCP port listening capabilities.

IV. Architecture

Figure 1 illustrates the architecture of this approach. Open Wonderland is a client/server architecture, whereas the JADE platform is used to create peer-to-peer systems. As shown in Figure 1, the link between these two separate architectures lies in the interface. The interface is actually a modified Open Wonderland module to which code has been added to start a JADE agent. The JADE agent is started via a runtime call, therefore the agent will be started on the local computer. However, the rest of the agents that make up the multiagent system (MAS) can be on other computers in the network. The agent started by the Open Wonderland module will communicate with the rest of the JADE agents using the FIPA specified protocol. One of the agents in the JADE/MAS communicates back to the Open Wonderland world by sending messages to a TCP port that has been activated on another Open Wonderland module, the Poster module.

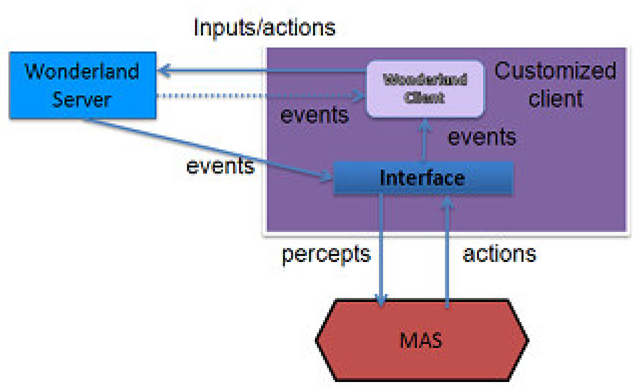

Figure 1. Architecture diagram.

V. Implementation

Implementation was supported by the loan of a SUN Ultra workstation with 8 GB of RAM. Open Solaris proved to be the only operating system that was installable on the SUN Ultra and supported both Open Wonderland and JADE. Open Wonderland v0.5 source code was downloaded from the SVN site http://openwonderland.googlecode.com/svn/trunk. Open Wonderland compiled without issue. Similarly the JADE framework version 4.0.1 was downloaded from the jade.tilab.com site and installed without issue. Learning the features of both Open Wonderland and JADE consumed the bulk of this research work.

With this approach Open Wonderland is virtually untouched with only the addition of a customized module and a script. For the proof-of-concept, the SAMPLE module was selected as it provides a complete 3D module that is easily customizable. The customized SAMPLE module imports the needed JADE libraries and code is added to start an agent. The scriptable Poster module listens to a TCP port and displays any received message. Likewise, the JADE framework is also virtually untouched with all modifications limited to a single agent module to include code to send messages to a TCP port.

VI. Results

A. *Proof-of-concept: Integration of BookTrading with Open Wonderland*

For the proof-of-concept, we selected a multiagent system from the JADE demonstration package, namely the Book Trading system. The Book Trading system is ideal for this proof-of-concept because it is a well known example of a multiagent system and is fully tested, allowing concentration on the integration of the multiagent system and the 3D virtual world and not on developing and debugging a new multiagent system. In addition, the Book Trading example lends itself to future modification to turn into a general information retrieval and filtering system as discussed in [15-18]. The general idea is that the agent started by the Open Wonderland system would be a "seeker" agent that communicates with a group of "provider" agents to find the real world information that is most relevant to the current situation in the virtual world. For this example, the Book Buyer agent plays the role of the information seeker agent and the Book Seller agents play the role of the information provider agents. Finding that an Open Wonderland module could start a Jade agent is only half the challenge; the other being that the Jade agent then needs to be able to communicate back the information that it has "found". Our approach is to utilize the Open Wonderland scripting capabilities to have a second module listen on a TCP port, and the Jade agent sends messages to this port

The results prove the concept that integration of JADE multiagent systems with the Open Wonderland 3D virtual worlds is possible and not overly difficult. The following screen shots illustrate. First the Open Wonderland Poster module is activated to listen to a TCP port. The SAMPLE module is invoked to start the Book Buyer agent. Figure 2 shows the Book Buyer agent communicating with the Book Seller agents. For this demo the Book Buyer agent is seeking a book named "MatrixMeetsSkyNet". A number of Book Seller agents have this book in its catalogue, each with a different price. Book Buyer agent negotiates with each of the Book Seller agents and selects to buy the book at the lowest price. Once the transaction is complete, the Book Buyer agent sends a message to a TCP port to communicate this information back to Open Wonderland where it is displayed by a Poster module. Figure 3 shows the result of the completed action.

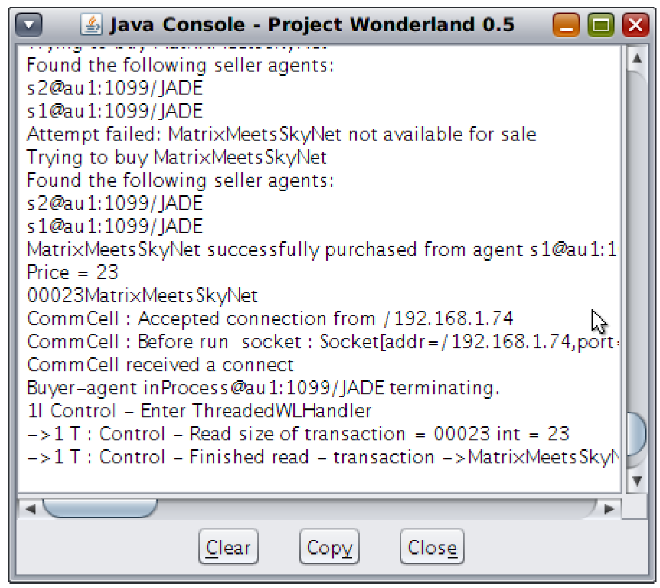

Figure 2. Book Buyer agent communicates with other agents to find and buy the book.

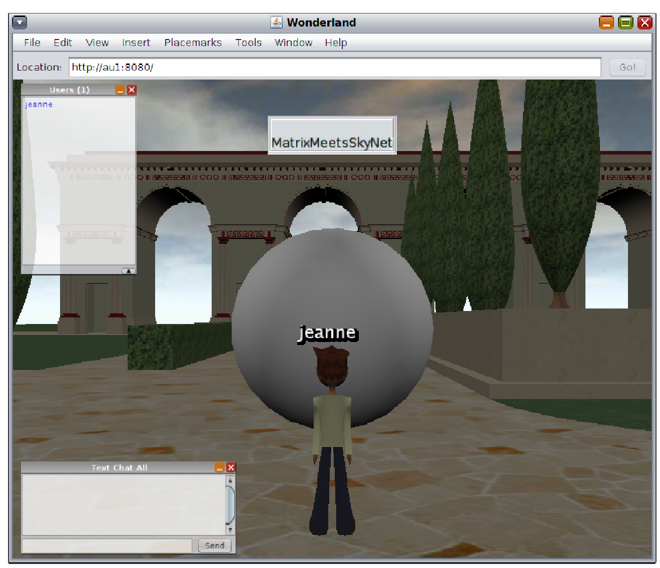

Figure 3. Book Buyer agent updates Poster

The main contribution of this proof-of-concept is to show that integrating multiagent systems into a MUVE can be accomplished without the need to make drastic changes to either the MUVE or the MAS. The fact that both Open Wonderland and JADE are written in Java and that JADE provides runtime creation of agents facilitates this integration.

B. *Case Study: Integration of QuizMASter with Open Wonderland*

As a case study for integrating a pedagogical multiagent system we selected to integrate a multiagent system previously developed by students of Athabasca University, named QuizMASter, which is a JADE Multiagent system that models a TV Quiz show [14]. QuizMASter is a pedagogically based multi-player, multiagent game developed in JADE. QuizMASter is composed of two main agents, the QuizMASter agent and the Player agent. The QuizMASter agent controls the game by sending questions to all of the Player agents. Human players control the player agents and provide the answers to the questions that are then passed to the QuizMASter agent via the FIPA protocol. Human players might or might not answer the question in the allotted time, but of those that do answer the question, QuizMASter will declare the Player agent with the best time to be the winner.

The goal for this case study is to use the same integration approach as was used in the proof-of-concept described above, namely to start a JADE agent from an Open Wonderland module and have the MAS system complete the game activities and then forward a message back to Open Wonderland. In this case the agent started by Open Wonderland is the QuizMASter agent. The QuizMASter agent looks for Player agents and if there are one or more Player agents, QuizMASter sends out a question to the Player agents. QuizMASter declares the Player agent with the fastest time to be the winner and sends a message to Open Wonderland poster module announcing the winner. QuizMASter cycles though a short list of questions, each time determining and declaring the winner.

Integrating QuizMASter into Open Wonderland required some minor changes to QuizMASter to remove the GUI since this is the agent started inside Open Wonderland and its GUI would have interfered with the immersive aspect of being in Open Wonderland. However, no changes were required to the Player agents. Figure 4 shows a group of players and the declaration of the winning player agent.

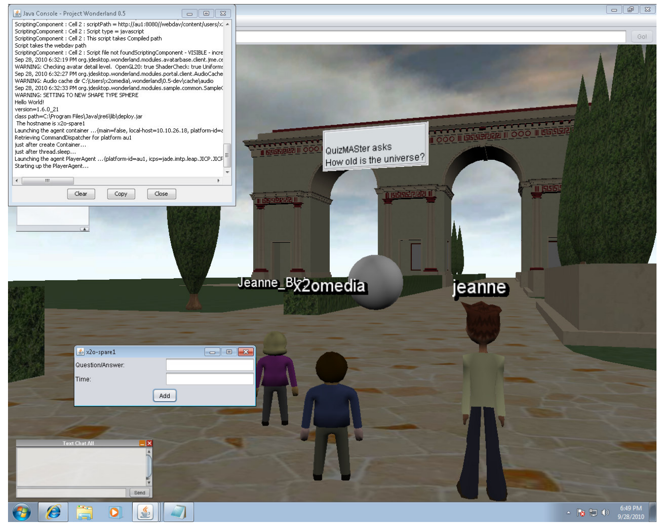

Figure 4. QuizMASter integration with Open Wonderland

Integrating QuizMASter into Open Wonderland demonstrates that this approach is versatile and could possibly be used to integrate other JADE MAS systems with Open Wonderland. Future work will be based on the knowledge that integrating JADE multiagent systems into Open Wonderland will not be overly difficult and opens the door to developing other types of MAS systems to support the learning environment.

VII. Conclusion and Future Work

Integration of Open Wonderland with JADE multiagent systems is feasible and not overly difficult. The main advantage of this integration approach is that it is a simple interface that is easily modified to support other JADE based multiagent systems. Integrating pedagogically based multiagent systems with 3D virtual worlds can enhance 3D virtual worlds to provide a more engaging immersive learning environment.

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