The City of Uruk: Teaching Ancient History in a Virtual World

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Abstract. In this paper we show how 3D Virtual Worlds can be utilised for teaching ancient history. Our goal is to build an accurate replica of one of humanity's first cities in a 3D Virtual World and provide history students with facilities to explore the virtual city and learn about its past in the simulated 3D environment. Unlike the majority of similar historical reconstructions, an important feature of our approach is having virtual agents that are capable of simulating everyday life of ancient inhabitants, which includes common tasks like eating, sleeping, working and communicating with one another. In order to offer educational value the agents act as autonomous tutors and are capable of sensing the students through their avatars and interact with them both in terms of performing joint actions and through verbal communication. We show how such virtual environments can be built, explain the technology behind its artificial intelligence controlled population and highlight the corresponding educational benefits. To validate the impact of using the 3D environment and virtual agents in history education we conducted a case study that confirmed the beneficial educational aspects of our approach.

1 Introduction

Virtual worlds have become a significant phenomenon in many areas of research, but education is one of the most prominent disciplines where virtual worlds found many applications. A number of studies confirm the importance of using Virtual Worlds for education [1], [2], [3] advocating the use of this technology in a wide range of scenarios, from training customs officers to teaching science to primary school students. One of the key benefits of virtual worlds that was exploited in prior works is the possibility of closely replicating an existing physical environment, so that participants conduct their learning activities in familiar settings and as a part of their learning, also study a remote physical location. But another significant benefit is that virtual worlds make it possible to immerse learners into a realistic reconstruction of a physical location that no longer exists. Such possibility opens new horizons for teaching subjects like ancient history.

Many promising works related to history-oriented virtual worlds focus on reconstructing ancient buildings, objects and even entire cities that are partially or completely destroyed at present. For example, "Rome Reborn" [4] represents

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a historically accurate reconstruction of a large part of ancient Rome. Visitors of historical simulations similar to “Rome Reborn”, are normally able to browse through 3D models of historically significant objects and inspect them from different angles and proximity. They can also select a particular object (i.e. Roman Colosseum) and closely explore its architectural details.

While the majority of history simulations are limited to recreating buildings and artefacts, some pioneering research also explores simulating human life, where reconstructed 3D environments are populated with virtual agents that behave similar to the ancient citizens that used to occupy the given reconstructed site. Most such work, however, employs the so-called “virtual crowds” [5]. Such crowds normally consist of a large number of avatars dressed as local citizens of the reconstructed site. The state of the art in using agent crowds in historical simulations is outlined in [6] where a virtual City of Pompeii is populated with a large number of avatars that walk around the city avoiding collisions. In this work the avatars are simply moving around and are not involved into historically authentic interactions, but simply serve as “walking decorations”.

Another important simulation employing virtual agents in historical reconstructions is the “Forbidden City” project [7]. The project simulates the one square-kilometre palace in ancient China grounds called The Virtual Forbidden City. Similar to other historical simulations a significant effort has been put into a realistic recreation of the architecture of the city, while a much smaller effort has been spared on the development of virtual agents. The agents in the Forbidden City are supplied with very limited “intelligence”. Their actions are highly scripted and their ability to interact with the users is limited to scripted monologues. The number of available agents is also quite low and the majority of those act purely as guides rather than as virtual inhabitants of the city.

The overview of existing work showed that virtual agents are rarely used in historical simulations and in those few cases when they are employed - their application is very limited. Furthermore, there exists little evidence that such agents contribute to the quality of learning in the domain of ancient history. Thus, in our project we investigate the use of historical 3D reconstructions, the role of believable conversational agents in such reconstructions and investigate the contribution of virtual agents to student learning. We have developed a historically accurate reconstruction of one of humanity’s first cities (Uruk) and populated the city with virtual agents that simulate daily life of ancient citizens of this city and are capable of complex interactions with their environment, as well as able to engage into complex multimodal interactions with students.

2 The City of Uruk

As a case study we have created a virtual reality simulation of the ancient city of Uruk in the virtual world of Second Life [8], based on the results of archaeological excavations and under supervision of subject matter experts. The objective of this simulation is to teach history students everyday life of ancient Uruk citizens.

To populate the city with virtual citizens (agents), we designed a number of scenarios that we obtained after detailed discussions with subject matter experts and history consultants. As the result of these discussions we identified roles the agents play, scenes they participate in, interaction protocols and social norms. We followed the methodology described in [9] to structure the knowledge received from the experts and transform it into formalisations suitable for developing the underlying multiagent system. The Virtual Institutions technology [10] was then used to build the normative system, produce agent code skeletons and enable agents automatically comply with social norms and being able to engage into interactions with other agents and humans, while adhering to the social norms.

The agents in the Uruk simulation represent a slice of Uruk society among which are fishermen families, priest, king and a number of workers (i.e. pot maker, spear maker). The agents can sense changes in the environment state, which result in them updating their beliefs accordingly. They are supplied with a number of internal goals and plans to reach those goals. The current implementation features fishermen families where men's daily routines include sleeping, eating, fishing and chatting. The females do house work, sleep, eat bring water from the well and go to markets. The king agent walks around his palace and invites students to ask him about his ruling strategies. The priest agent conducts a prayer in the temple, accepts gifts and explores the city. Other agents represent various workers: pot makers, spear makers, etc. Those workers produce goods, exchange goods with one another, attend the prayer and in their spare time explore the city, provide information to students and simulate social interactions with other agents. Fig. 1 illustrates agents "living" in virtual Uruk[1].

Fig. 1. Student interacting with an agent; Group of agents in the city centre

2.1 Implementing Virtual Agents

Our agent architecture is based on the BDI (Belief Desire Intention) model and functions similarly to Jack Intelligent Agents platform [11].

We have created our own agent library (VIAgents) for developing agents that follow our formal model. It provides them with communication facilities, planning and goal oriented behaviour. Each agent has a number of beliefs that map to a state of the virtual world and the institutional state, a number of goals the agent wants to achieve and the number of plans the agent can perform in order to achieve these goals. As the result of sensing the changes in the environment or events received from the institutional infrastructure or other agents, the

[1] A demo video is available at: `http://www.youtube.com/watch?v=15BaDjd7f1c`

agent may establish new goals or drop the existing goals and will start or stop corresponding plans accordingly. The BDI architecture is also extended with a learning mechanism that enables the agent to learn by example from a human expert. This part of the agent architecture is outlined in [12].

Interactions with the Environment. There are two parts of the environment the agents are involved in: the visual part rendered by Second Life and the normative part supported by Virtual Institutions technology. The agents interact with the virtual world by sending commands to the Second Life server through `libopenmetaverse` library [13] . Through these commands they are capable of moving around the virtual world, perform certain animated behaviours, perform commands on the objects in the environment and interact with other agents or humans. The normative part enforces the social norms on all the Second Life participants. Agents interact with this part by sending and receiving illocutions (text messages) to the AMELI system [14].

In the visual part the agents are capable of sensing the changes of the environment state, including the movement of the objects or avatars, new objects or avatars, actions performed by all participants, etc. In the normative part the agents can send and receive the institutional illocutions and sense the state changes resulted by these illocutions. The state of the visual part of the environment represents parameters like the time of the day, positions and transformations of the objects and agents in the virtual world. The institutional state corresponds to the set of currently active scenes and the state of each scene.

Object Use. To convincingly simulate daily life of the ancient people it was important to enable agents to use objects in the environment (i.e. take a spear, jump on a boat and go fishing). We implemented a fully-fledged object use library for the history simulation context, which includes a set of classes allowing agents to identify an object in the virtual world, attach it to the default attachment point, play a certain animation (e.g. rowing) associated with a given object, wear an object that is a piece of clothing, detach the piece of closing, drop an object to the ground and detach the object and hide it in the avatars inventory.

Goal Generation and Planning. Each of our agents follows a classical BDI model [11], where agents' actions are shaped by an individual agent's beliefs about the virtual environment, goals the agent must achieve and plans that represent a method of achieving certain goals. The Virtual Institutions technology [10] that is employed for encoding the normative layer of the virtual environment provides facilities for dynamic generation of goals for every agent when a certain institutional action is required to be performed. Some of the internal agent goal triggers are manually embedded into the agent code.

The changes in the virtual world (that happen as the result of actions of students or other agents) might result agents updating their goals. In order to achieve their goals they can use either static or dynamic planning. Static plans are instructions prescribed by an agent programmer and can't be changed at runtime. In the case of dynamic planning an agent can sense its current state in the environment and can react to environment changes re-evaluating its current plan. Rather than having a complete recipe provided for every situation the agent can encounter - the agent is simply given the list of possible actions and has to find a way of combining those to reach its goals. For making this task realistic, each action is supplied with its execution preconditions and postconditions. The preconditions define the state, scene and objects that the agent must have to execute the given action. The postconditions determine how those attributes will change after performing the action. Pre- and post-conditions are included as environment annotations and can be updated at run time.

Conversational Ability. All agents can chat with human visitors on a number of preprogrammed educational topics through the instant message and chat mechanisms provided by Second Life. In order to participate in a conversation our agents employ the ALICE chat engine based on the AIML language [15]. Each agent uses a number of AIML files that represent what can be seen as a common sense database. Additionally to this database every agent is supplied by personalised AIML files that reflect on its personality and the data relevant for its role within the virtual society. While conversing with students agents are capable of talking about their current state, the goal they pursue, reasons for pursuing this goal and give explanation about surrounding objects via the environment-, self-, and interaction-awareness model [16].

3 Validation of Learning Effectiveness

In order to test the learning effectiveness of using virtual worlds and virtual agents in history education, in our study we compared two different ways of learning history with two different sample groups. The first group, which we call the "Traditional Group", was advised to read a history text describing the facts about the city of Uruk (3000 B.C.) and its inhabitants. Participants in the second group (the "Virtual Group") were asked to visit the virtual Uruk to have an interactive learning experience about the same facts as the text based group. All study participants were undergraduate university students with no previous knowledge about Uruk. The two groups were aiming for the same learning objectives and contents, and were also able to access supervision if they required. It was assumed that any variation in student learning outcomes and appeal to students could be attributed to the group type factor. Based on our research objective of evaluating the learning of history and culture in 3D Virtual Worlds in comparison to text based learning, we have the following hypotheses:

- **H1:** Students in the virtual group will have significantly better learning outcomes in comparison to the students from the traditional group.
- **H2:** Student evaluations will show whether learning history has more appeal to the virtual group students than students in the traditional group.

Research Instruments. For testing the above hypotheses we aimed to collect quantitative and qualitative data about the usefulness of using virtual worlds and conversational agents in teaching ancient history. Therefore, we developed a questionnaire that contained two parts: the pre-test part collected the users' demographics and their background knowledge about Uruk. The second part was a post-test questionnaire aiming to test the knowledge gained about Uruk in each study groups. The pre-test questionnaire consisted of six multiple choice questions about the participant's demographical information and one pre-coded (open ended) question to test previous knowledge of the historical city. The post-test part of the questionnaire aimed at examining the knowledge gained in these user groups (an open-ended questionnaire for participants' feedback). Only students that showed having no previous knowledge about Uruk and ancient Mesopotamia were selected to continue after the pre-test.

The traditional group was provided with a text describing the city of Uruk, specifically it included people, buildings, climate of the city, historical significance, food, agriculture, trade and inventions made in that era. This text was designed with the help of subject matter experts. This text description comprised the same facts on which we developed our virtual city of Uruk.

The objective of the post-test questionnaire was to measure the student's knowledge of historical concepts presented in two different ways. The post-test questions fall under four major aspects to test the knowledge: climate and buildings, people/food/animals, agriculture and trade, Uruk inventions. These categories were based on the Uruk's prototype we developed in the Virtual World.

Participants. After the initial pre-test screening we selected 40 undergraduate students from the University of Technology, Sydney with no previous knowledge about Uruk and ancient Mesopotamia. All the participants were briefed about the study at the start of their respective sessions, by the researcher or their teacher. These students were then randomly assigned to one of the study groups, the traditional group or the virtual group. At least one researcher was present in each study session. The traditional group was assisted by their teacher on behalf of the researcher. A brief description of the study was given for 5 minutes followed by a class session which lasted about 30-40 minutes for two respective groups. The time required to fill out the post-test questionnaire was limited to 15 minutes and additionally 5 minutes were given to provide the post-test feedback.

3.1 Study Findings

The study showed a clear difference in performance gained between the traditional and virtual group students. The metric to measure any performance variations between the two groups was based on the marks achieved in the post-test exam. This performance comparison is illustrated in Table 1.

Overall, virtual group students outperformed the traditional group, with an average mark of 60.96%, while the students in the traditional group achieved an average score of 41.05%. The minimum performance achieved by traditional group students was 23% in comparison to the 40% minimum marks gained by the virtual group students. Similarly, the highest marks achieved in the traditional group were 66%, which was quite low compared to 88% achieved by the virtual group students. Moreover, these results show that virtual group performance stayed high for more students than in the traditional group.

Table 1. Student's Performance

Comparison: Traditional vs Virtual Group			
Traditional Group	Students(%)	Marks Obtained(%)	Weighted Average(%).
	15	23 - 25	
	35	32 - 39	41.05
	35	40 - 48	
	15	58 - 66	
Virtual Group	Students(%)	Marks Obtained(%)	Weighted Average(%)
	20	40 - 49	
	35	51 - 60	60.96
	25	61 - 69	
	20	77 - 88	

4 Conclusion

We presented a 3D simulation of the city of Uruk and showed how it was used for teaching ancient history and conducted an experimental evaluation of learning effectiveness of virtual Uruk. A group of students learning from a text document were compared to a group learning through interacting with virtual agents in the virtual world. The quality of learning was evaluated through conducting a written exam with students in each study group. The study outlined better performance achieved by the virtual group over the traditional text reading group. The study also showed that the virtual group was more engaged and willing to spend more time on learning.

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