Teaching Engineering Education using Virtual Worlds and Virtual Learning Environments

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Abstract—In recent years there has been significant growth in the use of 3D virtual worlds for e-learning and distance education. Virtual learning environments' support teaching and learning in an educational context, offering the functionality to manage the presentation, administration and assessment of coursework. However the presentation layer of virtual learning environment's are highly restrictive offering limited opportunities to create highly engaging and immersive user experiences. This paper investigates the suitability of one popular virtual world, Second Life™ for education and teaching purposes. It discusses its functionality and features and assesses its perceived limitations for use in educational context with a particular focus on the ability to link/integrate the virtual world with existing virtual learning environments. A number of demonstrative examples showing how virtual world/virtual learning environments can be integrated will be shown and the potential opportunities that exist in this area discussed.

Keywords: Virtual worlds, engineering education, serious games, virtual learning environments

I. INTRODUCTION

The constant emergence of disruptive technologies continues to offer new and exciting opportunities for educators [1]. Developments in recent years have seen web-based Virtual Learning Environments/Course Management Systems rapidly become an integral part of teaching and learning provision in further and higher education [2]. This evolution progresses unabated as educators strive to adopt and adapt web 2.0 technologies in the provision of more interactive teaching materials and learning environments which allow students the ability not only to view content but to interact and organize it to suit their personal needs [3]. Video games and virtual worlds are moving into the mainstream as traditional media industries struggle to keep up with digital natives and their desire for information, technology and connectivity [4-7].

This paper discusses and catalogues the suitability of one popular virtual world for educational and teaching purposes. It explores how Second Life could be used to create experiential based learning experiences in 3D immersive worlds [8-10]. A number of exemplars projects are introduced including the Engineering Education Island project in Second Life, which demonstrates how engineering education could be taught in virtual worlds. Approaches to integrating Virtual Learning Environments and Virtual Worlds are discussed and the practicalities of introducing a top down narrative with a formal teaching structure and explicit user objectives/learning outcomes in a virtual world scenario detailed. Section 2 of the paper discusses the Second Life virtual world and its functionality. Section 3 describes a range of University of Ulster research in virtual worlds. Section 4 provides an overview of how virtual learning environments can be integrated with virtual worlds. Section 5 demonstrates how complex learning experiences can be created in virtual worlds. Section 6 concludes the paper.

II. VIRTUAL WORLDS AS TEACHING TOOLS

Second Life (SL) is an Internet-based 3D virtual world launched in 2003 and developed by Linden Labs. Second Life facilitates an advanced level of social networking where residents can explore and socialize by participating in individual and group activities [11]. Second Life contains basic tools that allow users to create and script interactive 3D content. The ownership and rights to this content remains with the creator who can subsequently chose to retain it, give it away freely or sell it. This flexibility and intellectual property ownership and the fact that basic membership of Second Life is free has led to the establishment of a very active educator community in Second Life and many universities, colleges and schools using the environment for teaching [12]. Figure 1 shows a class being taught in real time Second Life where each avatar represents a logged on student.

Figure 1 Teaching in Second Life
III. UNIVERSITY OF ULSTER IN SECOND LIFE

The University of Ulster, Magee campus Second Life project began in September 2006 where initial research focused on the potential of virtual worlds for remote collaborative working and undergraduate/postgraduate teaching [13]. Engineering Education Island was created in Second Life to investigate if virtual worlds could be used effectively for teaching and learning in this context. When residents first arrive on Engineering Education Island they land at the welcome center, a large futuristic building which includes general information on the project and teleport links to the demonstrations and exhibits. Each floor of the virtual laboratory contains a range of interactive engineering demonstrations and simulations (Figure 2). Other facilities on the Island include a virtual lecture theatre where students can attend classes and collaborative working facilities where students can work together remotely.

![Figure 2 AC generator demo inside the virtual engineering laboratory](image)

Figure 2 AC generator demo inside the virtual engineering laboratory

Figure 3 shows a typical interactive simulation on the Island which demonstrates the main functions/components of a direct current electric motor. It allows the user to start and stop the motor and to view the magnetic fields. Scripting was used to turn on and the off magnetic fields and to create the particle system showing current flow.

![Figure 3 Direct Current Electric Motor (Interactive)](image)

Figure 3 Direct Current Electric Motor (Interactive)

IV. INTEGRATING VLE’S AND VIRTUAL WORLDS

Moodle (Modular Object Oriented Dynamic Learning System) is a free and open source e-learning software platform which allows users to create and manage teaching materials [14]. The extensive course management tools available in Moodle do not currently exist in most virtual worlds whose main strength in this context is the provision of immersive spaces for social interaction and experiential based learning [15+16]. The SLOODLE open source e-learning software project (Simulation Linked Object Oriented Dynamic Learning Environment) offers the functionality to link Second Life and Moodle and to exchange and synchronize data flow between the two environments [17]. Interaction with external applications is facilitated by the Linden Scripting Language which can communicate with the PHP driven Moodle database, using XML-RPC, and outbound HTTP requests. Initially the interactive demonstrations and simulations created on Engineering Education Island did not have any explicit user objectives, formal structure or learning outcomes and had no means of recording user actions/interactions. To remedy this a number of projects were designed where the interactive web based resource aspect was augmented with a virtual world. A Moodle website with Sloodle functionality was setup which was subsequently modified and extended for this project. The approach taken uses the following structure, a registered student logs on to Moodle to access and review the learning/course material. The practical aspect of the taught material requires the student to enter the virtual world and carry out a range of task based activities, either individually or as part of a group related to a single learning objective (Fig 4).

![Figure 4 In-world learner centered activities](image)

| PRACTICAL 1 | Become familiar with the theory and operation of DC generators |
| STUDENT NAME | Kerr Macle |
| TASKS | LEVEL OF COMPLETION |
| Enter virtual world and go to interactive simulation | Completed |
| View video in world about learning outcomes | Video viewed |
| View slides show showing tools | Slides viewed |
| Press button 1 to turn on power | Interaction 1 completed |
| Press button 2 to observe magnetic fields | Interaction 1 completed |
| Overall percentage of tasks completed | 100% completed |
| Total time student spend on assignment | XX hours XX minutes |

Completion of practical outcomes in this context is based on the student’s presence and interaction with in-world demonstrations in the virtual world. These actions are automatically recorded in Moodle for later retrieval and review by the student and the lecturer. The functionality required to track and record user actions/interactions is this way was not available in Sloodle at the time. Two simple extensions were required, a proximity sensor was needed which would record a registered avatar’s visit to the demonstrations in Second Life and a tracker component which would write to a database each time individual avatars interacted with the demonstrations e.g. press buttons to start animations. When the functionality was completed three initial exemplar projects were created based on augmenting and enhancing existing in-world demonstrations to validate and test the approach shown. In the practical now discussed the student is required to understand the operation of a DC electric motor (Figure 3), its individual components, their interaction and the effects of the magnetic fields.
When the student logs into Moodle they are presented with the list of practical assignments for this course. The student selects a practical assignment and is then given the details of tasks they need to complete inside the virtual world (Fig 5).

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Task Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1</td>
<td>Enter virtual world and go to interactive simulation.</td>
</tr>
<tr>
<td>Task 2</td>
<td>View video in world about learning outcomes.</td>
</tr>
<tr>
<td>Task 3</td>
<td>View slide show showing tasks.</td>
</tr>
<tr>
<td>Task 4</td>
<td>Press button 1 to turn on power.</td>
</tr>
<tr>
<td>Task 5</td>
<td>Press button 2 to observe magnetic fields.</td>
</tr>
</tbody>
</table>

Figure 5 List of tasks for practical assignment 1

They logon to Second Life and teleport to the required location to carry out the individual tasks. Each stage in this process is recorded inside Moodle. As the avatar approaches the interactive demonstration shown in figure 6 the sensor shown detects their presence, transmits this data back to the database and displays this information back to the student.

The Moodle page displaying the practical tasks is updated. In this practical session the student is required observe the DC motor operation and bring up the magnetic fields showing how they influence circuit behavior. As the student completes each individual task they receive feedback from the Second Life client (Figure 7) and the Moodle page.

The lecturer can also review the student’s progress and level of understanding by reviewing both the level of practical tasks carried out. This demonstrative example shows how virtual worlds and virtual learning environments can be integrated to create top down, narrative led, user learning experiences where user interactions inside the virtual world can be recorded and retrieved for analysis and assessment.

V. FETCH, DECODE, EXECUTE CYCLE OF A CPU

It was decided to create a more conceptually difficult demo which would help students understand and visualize how the fetch, decode and execute cycle of a CPU functions. Each component of the cycle was broken and replicated as a series of interacting life sized buildings in Second Life and a demonstration created that illustrates the steps undertaken in a CPU during the execution of a single instruction. This highlights the interchanging of control and operand information between the various building blocks of the CPU e.g. program counter (PC), program store (PS), instruction register (IR), operand memory (OM), data mux (DM) and arithmetic and logic unit (ALU). The example demonstration illustrates the six basic CPU steps in the multiplication of two operands. For example, step 1 highlights the role of the PC in providing the index to the PS. In this example the starting hex value of ‘00’ is used to index the PS (Fig. 8).

In step 2 the PS outputs the 8-bit contents of its memory (hex value ‘68’) as defined by the index ‘00’ (Figure 9).

This is fed to the IR in step 3 where it is partitioned into four 2-bit values as A (00), B (10), C (10) and D (01) (Fig. 10).
Each of the four 2-bit values plays an important role in the control of the CPU. For example, in step 4 the 2-bit values A and D are used to index the OM. In this example the decimal values ‘4’ and ‘6’ are output from the OM to the data mux where they will be fed into the ALU (Figures 11+12).

Step 5 outlines how the 2-bit value B (10) informs the DM that the resultant value from the ALU is to be stored back in the OM when the ALU is finished (Figure 13). Finally, in step 6 the 2 bit value C (10) informs the ALU that a multiplication operation is to be performed on the data present at its inputs. The ALU performs the multiplication of 4 x 6 to provide the computed decimal value of 24 (Figure 14).

To assist in evaluating a student’s understanding of the CPU operations and interchange of data a further demonstration was created with an error introduced in step 6 where the data value C being fed to the ALU is different from the original value stored in the IR of step 3 (Figure 15). For example, this time step 1 highlights the PC hex value of ‘01’ which is used to index the PS. In step 2 the PS outputs the value ‘40’ as defined by the address value ‘01’. Step 4 shows the IR binary contents of ‘0100 0000’ where A='00', B='00', C='00' and D='01'. In this step the 2-bit values A and D are used to index the OM and read the decimal content values ‘6’ and ‘4’. Step 5 outlines how the 2-bit value B (00) causes the resultant output of the ALU (i.e. when the result is computed) to be fed back into input 1 of the ALU (feedback path options is selected). A simulated fault occurs in step 6 where instead of issuing the C value of ‘00’ (add operation) to the ALU, the C value of ‘01’ (subtract operation) is sent which causes the ALU to perform a subtract operation. This is illustrated in the demo where the output of the ALU subtract operation (6-4) is the value ‘2’ (Figure 16).
This is incorrect as the IR told the ALU to perform an addition operation (6+4) where the resultant decimal value should be ‘10’. The focus of this fault is to encourage student to examine the IR where the binary instruction is divided into its four 2-bit patterns. This is often the most difficult aspect of the CPU as this is where the instruction information is used to control the OM, DM and ALU components. By tracing back through the sequence of steps, and by comparison with the steps in the ‘working’ demos, students will be able to see the fault occurring in the output of the IR data. At the end of the “faulty demo” the student is questioned on their understanding of what went wrong is this simulation. If they answer correctly then they are congratulated. If they answer incorrectly then they are asked to rerun the simulation and take the test again. All of these interactions are recorded in Moodle for review by the student and member of academic staff. This simulation will be used for teaching in the forthcoming academic year and student feedback will be recorded and assessed to evaluate if this approach is an effective way to teach.

VI. CONCLUSION

This paper provided an overview on ongoing research at the Intelligent Systems Research Center, University of Ulster, Northern Ireland into the use of virtual worlds and virtual learning environments for teaching. Engineering Education Island was introduced and a range of practical examples were demonstrated which showed the flexibility of the Second Life virtual world as a viable tool for educators. It is acknowledged that some of the initial examples shown here are simplified versions, with limited interaction of what would be useful in real world practical’s for students but the addition of the fetch, execute and decode CPU simulation shows that it is possible to make complex and highly interactive demonstrations using in-world tools that can be used for teaching. The paper also demonstrates that it is possible to integrate virtual learning environments and virtual worlds to harness relative strengths of each platform e.g. the course management features of virtual learning environments and the immersive/highly interactive nature of virtual worlds to create engaging learning experiences for students. The use of virtual worlds for this purpose is in its infancy and there will be many hurdles to overcome until their use becomes widespread and mainstream. Educators will have to embrace and adapt to these technologies and discover ways to use them effectively and appropriately.

REFERENCES