COLLABORATIVE DESIGN USING VIRTUAL WORLD TECHNOLOGY

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Abstract: Collaboration and teamwork in support of engineering design are an integral part of the engineering process and undergraduate engineering education. Virtual world technology provides an immersive, engaging, dynamic and highly interactive 3D environment which supports dynamic 3D modeling and collaboration among participants who may be geographically dispersed. Successful case studies of collaborative student design of prototypes in a virtual 3D environment in the area of home robotics and smart home technology are presented. The increasingly sophisticated 3D building tools, physics engines and the in-world community support of 3D virtual worlds will position this technology to strongly support collaborative designin the future and to alsosupport new models of education delivery, such as web-based, hybrid, and massively open online course (MOOC) models.

Keywords: collaboration, design, robotics, education, virtual worlds

Introduction:

Collaboration and teamwork in support of engineering design are an integral part of the engineering process and undergraduate engineering education. As the educational landscape expands to include web-based, hybrid, distance education, international, and massively open online course (MOOC) delivery models, there is an even greater need to facilitate on-line collaboration and community among learners to facilitate the engineering design and prototyping process. Virtual world technology is one such solution which provides an immersive, engaging, dynamic and highly interactive 3D environment which supports design and collaboration among participants who may be in a traditional educational setting or geographically dispersed. The advantage of virtual worlds is that it supports in-world collaborative 3D modeling and animation as well as avatar communication in both voice and text. The virtual world platform provides an immersive environment which supports the team design process, the review process and the presentation process.

There are examples of successful utilization of virtual worlds to support collaborative design in the literature.Ehsani and Chase [1] discuss the uses of virtual worlds with distributed design teams to reduce the time to develop prototypes and reduce overall costs, and they included the review of several case studies in the architectural and construction field. One such case study involved the construction of a virtual 3D model of a hotel which allowed online users to enter and navigate the virtual hotel building and provide feedback on features and layout. The military has used virtual worlds to develop 3D immersive prototype models to collaboratively design command and control facilities for submarines[2]. The study also indicates that virtual world models can be used to visualize the flow of data, information and communications, and this is due to the interactive and programmatic nature of virtual world software.Merrick, et al. [3] describes a set of educational case studies involving virtual world support of collaborative design and includes discussion on the cognitive design process and support for human-computer interaction. Finally, Wigert[4] describes the value of virtual world collaboration in terms of enhanced engagement of participants in the design team and discusses the role of the facilitator in leading virtual teams.

At the Penn State Abington campus (Abington, PA), this author has integrated elements of virtual world technology, using primarily Second Life, into an introductory information sciences and technology course since 2007. Student teams in this class have explored a variety of team-based activities involving 3D building in topic areas which include science education, architecture, virtual support for charitable organizations, medicine, etc. On-line, globally accessible, 3D interactive exhibits of the student projects were also constructed within the virtual world [5].Students in engineering classes at our campus have also designed interactive engineering exhibits and various prototypes to support coursework. An interactive mobile robotics virtual laboratory was developed to instruct virtual users in the basic programming techniques to direct a robot to successfully navigate a maze. Due to the persistence of virtual world platforms, this virtual, interactive robotics laboratory (as well as all other virtual world user content) is available online at all times to an international audience [6]. In general, virtual worlds offer more immersive and powerful user (avatar) interaction, collaboration and in-world building, but may offer less in the way of accurate and precise models that can be achieved with traditional 3D building tools, such as 3DStudioMax or AutoCAD. Many virtual world platforms, however, allow users to import mesh models from a variety of industry-standard 3D modeling tools. For example, in a virtual world, it is possible to have a user or group of users “walk through” a large model of a virtual building, reactor, or hospital, etc. that would not be possible with traditional 3D modeling tools. It is important for educators to understand the many tradeoffs in using these 3D technologies effectively.

In the next section I will describe a key engineering design challenge in the area of mobile robotics which has been successfully supported by virtual world technology at our institution. This example includes the collaborative student design of prototypes for home robotics and smart home technology. Second Life (https://secondlife.com) virtual world technology has been chosen as the virtual world platform for these activities due to the low cost, availability of a free basic account for students, andthe availability of easy to use, in-world 3D building tools and scripting tools. The in-world building tools also support capabilities to modify permissions for editing objects among a group of users and this can facilitate collaborative building and design, especially in the area of prototyping and communicating ideas. Another advantage of the Second Life tool is the existence of an established and experienced community of educators and researchers with active presence in Second Life to provide resources for support, mentorship, and in-world evaluation of student team design projects.

Virtual World Collaborative Design Experience:

In this section I will describe a virtual world team design project in the area of home robotics which was a group assignment in an introductory robotics course offered in the spring 2012 semester at Penn State Abington. This design project demonstrates many of the advantages of using a virtual world for collaborative design in a course environment. Teams of students (ranging in size from 2 to 4 students) were tasked to design, build, and demonstrate a robot prototype which represents an innovative robotics product or solution to improve the quality of life in a home environment. Robot themes chosen by teams of students included a plant watering robot, a window washing robot, a food serving robot, a security robot and a robotic wheelchair.This virtual world task was a 4-week project in a 15-week course in which the student teams were also building and programming real-world autonomous robots and exploring other tools, such as Unity 3D modeling tool. All of the robot prototypes described here were constructed by the student teams using Second Life. Scripts to animate the robot models were made available to the students to insert into their designs to provide basic motion either through a list of motion commands or through keyboard commands. The scripting language in Second Life is a proprietary C-like state machine based language and requires training in order to achieve proficiency. However, there are many existing scripts, or scripts that can be easily modified, whichcan provide a good deal of functionality (motion, particles, user interaction, etc.) when required. Typically, students are not expected to develop custom scripts in a short virtual world course design module such as described here.Several of the robot prototypes are shown in the following figures. Figure 1 below depicts a 3Dmodel for a plant watering (and bowl filling) robot. In the picture, two student avatars are demonstrating the robot for the instructor. More importantly, the robot is being demonstrated in a virtual living area that was setup by the instructor prior to the group exercise to simulate a typical home environment. It is critical that the initial robot prototypes are simulated in an environment which is realistic so that students can see the effect of overall robot dimensions, speed, andthe potential interaction with humans and other objects with the robot. Second Life enables the user or team of users to edit and modify objects, such as the robots depicted in the figures, within the online environment in real-time with other users "seeing" the model changes as they are executed. The home environment with living room and kitchen can also be modified (by any avatars who have edit permissions) in-world without using any external tools. Furniture and appliances shown in the virtual living area can be constructed by students or the instructor, or they can be purchased within the virtual world from vendors who distribute (or sell) useful objects constructed by other residents of the virtual world. The existence of a community of builders and scripters who can share and exchange products and tools is one of the advantages of the Second Life platform. Figure 2 shows anotherview of the plant watering robot with the particle animation which simulated water flow from the robot.

Figure 3 shows a food serving robot prototype in a living area with the instructor'savatar seated in the virtual living room. At this point, the instructor can be evaluating the robot design in terms of requirements and usability and discussing (in either text or voice) the evaluation with the students who might also be in the virtual world. Users in the virtual environment have complete control of the position of their camera (view) and may view the designs from any perspective. At any time, any users from around the globe with an internet connection and a Second Life account can be invited to join the group discussion on the design and operation of the robot. Typically, the Second Life platform can handle 30 to 40 avatars (users) in any one location (or sim) before encountering performance problems. Students and other users may also visit the designs at a later time and evaluate the robot 3D models. This type of realistic immersion and dynamic interaction is generally not available in traditional 3D modeling tools which do not employ virtual world technology. Figure 4 shows a window washing robot prototype along with the student team setup in an exhibit presentation area. Exhibit areas allow team members and students from other teams, or visitors from any location to visit the site and experience and evaluate and learn about the robot designs. It also allows any visitors or classmates to interact and converse with the design team members at the site of the model. Generally, we have organized a virtual open house or poster fair at the conclusion of the design modules in which visitors from around the globe are invited to interact with the student teams and interact with the robot models. In this way, the team design and 3D building phase, review and iteration phase, and presentation phase can all be accomplished in the virtual world environment at a low cost and with a high educational value.

Observations and Future Directions:

The virtual world case study described in the above section highlighted many of the advantages of virtual world technology, with an emphasis on the Second Life platform. While this exercise was very successful there are many areas for improvement in the current technology. Specifically, there were lag limitations at times using the Second Life tool, especially for students who did not have access to high speed internet or satisfactory graphics cards. Some aspects of the Second Life building tools and edit permissions protocols were perceived to be challenging by some of the students as well. As was mentioned, the scripting language is not an industry standard language familiar to students with existing programming skills. Currently, there is no direct method to export 3D models out of the Second Life virtual world for archiving purposes, but Second Life is improving in the area of importing mesh models. There are also limitations with the physics engine (Havoc) in Second Life and there exist mechanical modeling limitations such as the lack of axels and hinges which can restrict some designs. The physics engine in Second Life does allow for collision detection, friction, forces, impulses and gravity. Overall, the advantages of the Second Life platform outweighed the disadvantages for our design objectives. We are also investigating Open Simulator (OS) and Unity-based virtual technologies.Open Simulator (http://opensimulator.org) is an open source virtual environment effort which offers similar technology as Second Life and uses the same viewer client technology. OS also provides a lower cost for virtual land and supports the more advanced Open Dynamics Engine (ODE) physics engine. However, the current community base is not as strong as the Second Life community if that is a critical component to your objectives, and OS users experience some of the same performance issues as Second Life users. Unity (http://unity3d.com/) offers a more sophisticated 3D editor and ability to import industry standard assets, but does not currently allow native in-world object editing or avatar collaboration, immersion and interaction as other platforms. Unity simulations mayalso be executed in a web browser and thereby do not require the user to download client software. Additionally, there is support to port Unity 3D simulations to a variety of mobile devices, such as smart phones. Jibe (http://jibemix.com/) is an example of a virtual world technology which uses the Unity editor as a front end but extends the platform functionality by providing avatar support for communication, interaction and collaboration, however in-world object creation and editing is not currently supported. It is anticipated that virtual world technology will continue to advance greatly in the near future, and the choice of the appropriate virtual world platform will greatly depend on design requirements and educational objectives.

Summary and Conclusions:

This paper has demonstrated the usefulness of virtual world technology to support and promote collaborative design. A successful case study of virtual mobile robot design for home robotics was presented to illustrate the key advantages of the virtual world approach,using Second Life technology. Based on our experiences, key advantages of virtual worlds include the ability to create and animate 3D models and prototypes,and to communicate and collaborate as avatars in an immersive environment. Ideal virtual worldtechnology tools should include in-world shared 3D editing, animation (preferably with industry standard programming languages,) ability to import mesh models, a sophisticated physics engine, highly interactive avatars and a strong community of users. While this case study was employed with students in a largely traditional classroom setting, it can be posited that based on the successes of the online collaboration described, and the fact that the students and the instructor could have achieved similar results independent of where they were physically located, that many of the results would be promising to supplement web-based, distance education, hybrid, international or MOOC-based educational design experiences.Clearly the virtual world platform feature set must be well matched to the educational objectives. It is hoped that these results and interpretations described here will help educators embark on integrating virtual world technology into collaborative design projects.

References:

[1] Ehsani, Ehsan and Chase, Scott C., "Using virtual worlds as collaborative environments for innovation and design: lessons learned and observations from case studies in architectural projects," Proceedings of the 27th Conference on Education in Computer Aided Architectural Design in Europe. eCAADe, Istanbul, (2012) 523-531.

[2] Aguiar, S., Monte P., "Virtual Worlds for C2 Design, Analysis, and Experimentation," Proceedings of 16th International Command and Control Research and Technology Symposium, Quebec City, Quebec, Canada, June 21-23, 2011.

[3] Wigert, Benjamin, et al, "Collaboration in Virtual Worlds: The Role of the Facilitator," 45th Hawaii International Conference on System Sciences (2012) 973-982.

[4] Merrick, K., et al., "*Case studies using multiuser virtual worlds as an innovative platform for collaborative design*, " Journal of Information Technology in Construction (ITcon), 16 (2011) 165-188.

[5] Avanzato, R.L., "Second Life 3D Virtual World in a Freshman Information Sciences and Technology Course," Proceedings of National ASEE Conference, Pittsburgh PA, June 2008.

[6] Avanzato, R., "*Mobile Robotics Laboratory in a Virtual World*." vol. 2, no. 4, Computers in Education Journal (2011) 98-103.

Figure 1. Plant Watering Robot in Virtual Home Facility (instructor with student avatars)

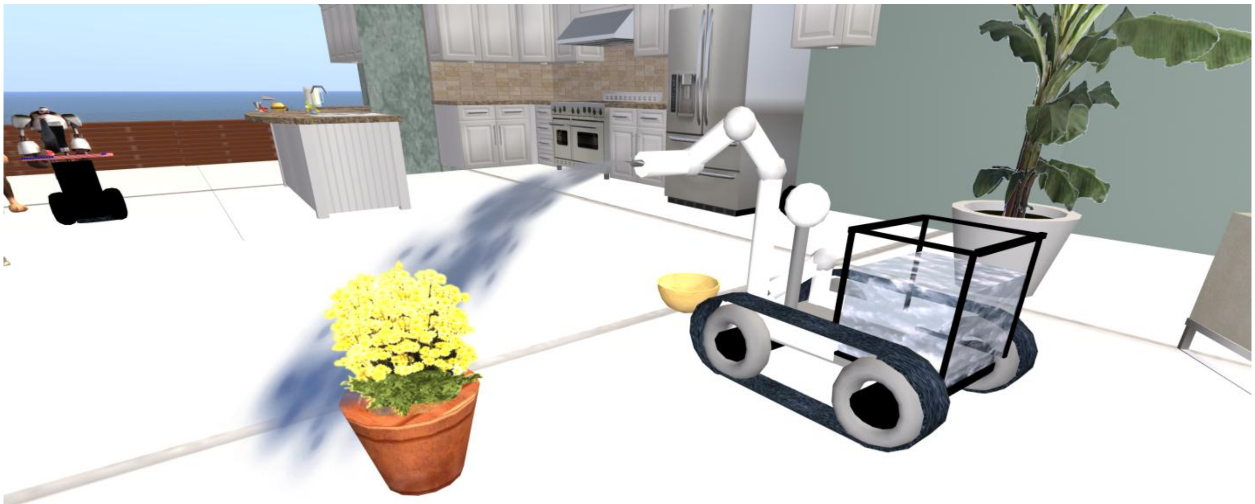

Figure 2. Plant watering robot with particle emitter animation

Figure 3. Food Serving Robot in Virtual Living Room (with instructor avatar)

Figure 4. Window Cleaning Robot and Exhibit Space with Design Team