A Review of Applications of Computer Games in Education and Training

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Abstract - Scientists, engineers and educators are increasingly using environments enabled by advanced cyberinfrastructure tools for their research, formal and informal education and training, career development and life-long learning. For instance, academic institutions as well as private training and education companies have recently started to explore the potential of commercially available multi-player computer game engines for the development of virtual environments for instructional purposes. Most of these developments are still in their early stages and are focused mainly on investigating the suitability of interactive games for remote user interaction, content distribution and collaborative activities. Some of the ongoing projects have additional research objectives, such as the analysis of patterns of human behavior and the study of the collaboration between users and their interaction with virtual environments. A few other developments are aimed at utilizing computer game technologies as a platform for personnel training and educational laboratory simulations. This paper provides a review of the current state of computer game applications, with a special focus on education and training implementations.

Index Terms - Scheduling, Online laboratory, Remote experiment, Sharing, Virtual experiment.

INTRODUCTION

In recent years, video games have begun to impact students’ lives. Most high school and college age pupils are highly accustomed to and very skillful in playing computer games. A remarkable feature of video games is their power to motivate. Computer game features such as active participation, intrinsic and prompt feedback, challenging but achievable goals, and a certain degree of uncertainty and open-endedness contribute to these games’ appeal. Recent research has shown that game-based learning has similar characteristics as problem-based learning in that specific problem scenarios are placed within a playing framework [1]. Games have many characteristics of problem solving activities, for instance the construction of a problem context, multiple paths to a specific goal, collaboration in the case of multiple players, unknown outcomes, etc. Furthermore, they add elements of competition and chance.

A game engine is the essential core of a computer game with reusable functional components (e.g. graphics rendering, audio output, in-game physics modeling, game logics, rudimentary artificial intelligence, user interactions as well as multi-user networking) and is usually accompanied by a software development kit (SDK). These SDKs enable others to develop customized content that is then utilized in conjunction with the game engine. Currently, several computer game engines are commercially available and have been used by developers to create very realistic massive multiplayer game environments (e.g. World of Warcraft [2], Everquest II [3], Second Life [4]). At present, some of the better known commercial game engines representing the cutting edge of technology in first person perspective graphics are Epic Game’s Unreal engine [5], id Software’s DOOM 3 engine [6] and Valve Corporation's Source engine [7]. The type of games that these engines were designed for are predominantly “first person shooters”, where the user controls the movements and actions of a computer character and the visual display mimics the perspective of what the in-game character would see with his/her own eyes.

Recently, computer gaming [8] started to be used in many fields, including medicine, disaster response and military training. However, creating educational games is not simply a matter of adding educational content to some existing game environment. Instead, the software itself should be designed based on evidence that the particular educational content can be effectively delivered in a computer game environment [9].

CLASSIFICATION OF GAME ENGINE APPLICATIONS

Computer game engines are applied for educational, training, research and other purposes.

Educational applications: Taking advantage of the favorable characteristics of computer games, existing multi-player computer game engines can be utilized as a means for creating educational tools that have the potential for enabling students to learn in an engaging manner. These game-based educational simulations involve synchronous student interaction through a computer network, and they will benefit the students by stimulating the different modalities of learning, i.e. visual, audio, read/write and kinesthetic [10]. For instance, a chemistry simulation was implemented using the TV3D game engine [11] as a development platform [12]. Similarly, a game-based collaborative virtual environment that supports the early
stages of design in the context of architectural education was introduced [13].

Training: Various groups have also explored training systems based on computer game engines, stimulated by the affordability of such systems in combination with the ubiquity of powerful personal computers. For example, simulations of military scenarios [14],[15] were developed for training purposes. Similarly, the potential for using multi-agent tactical simulations as training software was investigated [16], wherein the Unreal [17] game engine and its associated main simulation servers were interfaced, thus enabling the use of common PCs as a low cost replacement to the expensive proprietary equipment used previously in such tactical simulations. Various computer game platforms [18],[19] were used to develop virtual simulations of accident scenarios in chemistry laboratories, stipulating that this approach is more effective than distributing safety regulations to the students in the traditional paper form.

Research and other: The Unreal game engine formed the basis for research aiming to achieve refinements of the human controller and robotic interface of urban search and rescue robots [20]. Several computer game engines were investigated as flexible, robust and inexpensive environments for exploring the development of human level artificial intelligence in complex environments [21]. Software systems that are capable of adapting their responses to the context of the attempted user task were implemented using a game engine [22]. In the open-source CaveUT project [23], the Unreal game engine was used to enable immersive projection-based virtual reality applications through displays in multi-screen enclosures, which provide users with a high-performance, low-cost virtual reality alternative.

EDUCATIONAL APPLICATIONS

Recently, massive multiplayer online games such Second Life [24] (created by Linden Research, Inc. [25]) have become more than just virtual environments for chatting. Second Life was programmed to be an open-ended virtual environment and features a high level of flexibility. It enables its users to customize their avatars as fantasy creatures and build almost anything they could imagine. An increasing number of organizations and institutions are using it to implement applications that have a purpose other than providing for an entertaining pastime, and it has developed into a platform used for educational, research and even therapeutic purposes. For instance, it became a place for business school students to test entrepreneurial talents. In a program presented at the 2005 Supernova conference on emerging technologies and business implications [26], students of the Wharton School and conference attendees were immersed in Second Life and encouraged to start businesses, to advise some businesses already in existence and to compete against each other. Elon University in North Carolina [27] is another business school that is employing Second Life as a way of building and testing entrepreneurial skills.

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Second Life and many other massively multiplayer online (MMO) games offer the ability to start in-world businesses that sell things like custom clothing, vehicles, housing and more for use inside of the game. What sets Second Life apart is the freedom to create and have open-ended social interactions with all its members who pay a one-time fee. Second Life’s almost 14 million currently registered users [28] surpass other MMOs, such as World of Warcraft, EverQuest and Ultima Online, just to name a few [29]. The success of Second Life is probably based on the fact that many industry observers feel that it offers the best platform for mixing social interaction, play and the opportunity to tackle serious issues, since the game is not restricted to a narrowly defined objective [30].

The Berkman Center for Internet & Society at Harvard Law School and the Harvard Extension School [31] is a virtual environment created in Second Life on an in-world island. A course called “CyberOne: Law in the Court of Public Opinion” [32] is the first class at Harvard University and the Harvard Extension School to be offered in part in a virtual environment. The corresponding course video, lecture and project materials are available for free in Second Life to anyone with an Internet connection. Students taking the course meet weekly with their instructors and fellow students in Second Life for usual classroom activities as well as innovative projects that take advantage of the large amount of possibilities of the Second Life environment. CyberOne represents an ongoing process of pedagogical innovation and experimentation, with inquiry into openness, new technologies and related policy, learning and social media. Furthermore, a wide spectrum of Web issues, including governance, privacy, intellectual property, antitrust, content control and electronic commerce is also explored.

As another example, Middletown Island was created in Second Life by the Center for Media Design [33] at Ball State University in Muncie, Indiana, for the freshman composition course, which was taught as a virtual class. The focus of this class was to help students learn how to research and write in a virtual setting. In the Second Life implementation of the course, the students sat in a circle, debated and communicated via a public instant messaging system. Then, the instructor printed the recorded dialogue as classroom notes. As a semester project, the students built an exhibition area and invited other Second Life users to visit and review their work. Reportedly, in excess of 300 people from around the world visited during a two-hour period and gave the students’ work an exposure far greater than would have ever been possible using conventional methods.

A virtual chemistry laboratory simulation was developed at Brigham Young University [34],[35] (see Figure 1). Thousands of test tubes holding molecular solutions were photographed. Then, working with video game designers, a simulated laboratory environment was created that enables students to mix chemicals in virtual beakers and observe the resulting chemical reactions. Since its conception, the virtual chemistry laboratory has had
students at computer terminals around the country perform experiments that would be too costly or dangerous to perform at their local high schools.

FIGURE 1
VIRTUAL CHEMISTRY LABORATORY [34]

“Cell Biology” [36], a project where students collect data from the cells of an onion root and use it to calculate the duration of each phase in the cells’ division, was developed at the University of Arizona. The science courses offered by some online high schools draw on multiple Internet sites that provide data and subsequently lead students through an analysis.

Similarly, a virtual pig dissection module was developed at Whitman College in Walla Walla, Washington [37] (see Figure 2). This tool was designed to help students in preparing for tests and to offer a substitute for those students who, for ethical or other reasons, object to working with once-living specimens. With the click of a mouse, a virtual scalpel can be used to lay the pig’s kidney open, and its internal regions are highlighted by blinking labels. According to student comments, having enlarged highlighted images is useful, which is not possible in a traditional school laboratory environment.

FIGURE 2
VIRTUAL PIG DISSECTION ON THE WEB [38]

Research on spaces and tools in real and virtual educational environments (WISE environments [39]) is being pursued at the RWTH Aachen in Germany [40]. This work is designed as the starting point of a thread of inquiries into linking real-world and virtual learning environments and exploring the resulting synergies. SecondReiff [41], a virtual extension of the campus of RWTH Aachen, offers the environments and tools through which students and faculty can communicate and work together productively in new ways. The project features three distinct, vertically stacked zones. A so-called “XXL Workbench” located at sea level enables the students to practice architectural design collaboratively in real time, upload necessary architectural drawings onto the grid and manipulate the topography (see Figure 3).

FIGURE 3
SECONDREIFF XXL WORKBENCH [42]

Above this zone, reference images can be posted in a Media Center. Lastly, a General Communications Area forms the top level, which is built upon the very same logic that is used in Second Life itself. This area is divided into a mainland with project-specific areas and many islands claimed by individual students. Besides the immediately visible differences to most other projects in Second Life, SecondReiff is based on another concept. While most Second Life locations limit their interactions to avatar-to-object relationships, SecondReiff offers tools and scripts that actually link avatars to one another and expand the available modes of communication and information exchange between them. Communication between the avatars, formal presentations and the ability to actually collaborate in real time and on a large scale represent an environment with previously unimaginable productivity and technological possibilities.

Based on Half-Life 2 [43], a first-person shooter computer game using the Source game engine, Garry’s Mod (i.e. modification) [44] was developed, which represents a “physics sandbox” that allows the players to spawn objects, connect them with various constraints and thus create working systems that obey the laws of physics, such as a controllable model of a car (see Figure 4). Similarly, the Wire Modification project [45] to Garry’s Mod allows players to wire gates, sensors, inputs and outputs together in order to form working primitive computers or machine-like contraptions. The wires used to connect the electronic elements are energy beam models that act as a medium to carry the output of one wired entity to an input of another. The remaining electronic elements are programmed to simulate the logic of their real-life counterparts. In
conjunction with the Havok physics engine [46], this can be used to control various mechanical processes with wire-enabled constraints, special game functions or entities that affect object parameters.

FIGURE 4
CONTROLLABLE MODEL OF A CAR CREATED USING GARRY’S MOD [47]

Garry’s Mod and Wire Modification inspired the development of a virtual laboratory environment at Stevens Institute of Technology. This system enables the students to assemble an experimental apparatus (an industrial emulator system used to demonstrate the concepts of gears, belts, inertia of machine elements, rigid vs. flexible machines) within the game-based virtual laboratory environment [48] (see Figure 5) and subsequently to either carry out experimental procedures using a remotely accessible actual experimental setup of the industrial emulator system or perform virtual experiments using a software implementation of the experimental setup [49].

FIGURE 5
VIRTUAL STUDENT LABORATORY

Using the approach of combining the game-based laboratory environment with remote and virtual experiments, the students can repeat the laboratory experiments more than once at their own pace as opposed to having to complete the laboratory procedure during the allotted time as in the traditional hands-on mode. The assessment data obtained from a pilot implementation into a junior-level mechanical engineering course indicated that the students improved their knowledge of the concepts taught in the lecture component of the class and expressed general satisfaction with this laboratory approach [50]. The results of the assessment study furthermore suggest that game-based learning environments have the potential for developing into an educationally viable complement to traditional pedagogical tools and warrant further investigation.

TRAINING APPLICATIONS

An elaborate surgery simulator is currently being developed at Rensselaer Polytechnic Institute. This simulator will allow surgeons to manipulate virtual human organs in real time, thus enabling them to acquire crucial skills without using cadavers or risking human lives (see Figure 6). The ultimate goal of the project is to create a complete virtual human. Upon completion of the required giant database of virtual human anatomy models, the simulation would look and feel real and allow the user to “touch” and manipulate it using haptic interfaces such as SensAble Technologies’ Phantom devices [51] or Meta Motion’s CyberGlove [52].

Another human simulation currently under development is HumanSim™ [54] (see Figure 7). This system is being created based on the Unreal game engine by integrating it with a high-fidelity physiologic-pharmacologic model for experiential learning. The simulation scenarios are being programmed so as to emphasize learning-by-doing and to provide training-to-proficiency in rare, complicated or otherwise error-prone tasks. Also, two instructional 3D simulations for heart surgery procedures were developed, which demonstrated new treatments for atrial fibrillation in the heart. The first animation was an open chest procedure while the second demonstrated laparoscopic access in a closed chest setting.

FIGURE 6
VIRTUAL MODEL OF SURGICALLY CUTTING A KIDNEY [53]

FIGURE 7
HUMAN SIMULATOR [54]
So far, the few surgical simulators currently on the market are not very popular yet with the medical community, largely because of their lack of realism and since they rely mostly on simplistic graphics for representing human tissue. Furthermore, the haptics technology used to let surgeons “feel” their actions is not mature enough yet for simulating interactions with soft biological tissue.

A virtual training space in Second Life named Play2Train was designed as part of Idaho’s Bioterrorism Awareness and Preparedness Program [55]. This virtual environment spreads over two Second Life islands, whereby one island hosts a virtual town and the other a virtual hospital. It represents a virtual world designed specifically to meet the distinctive training needs of the professionals who will be on the scene in the event of any large-scale disaster. Play2Train provides opportunities for training through interactive role playing and is the foundation of what would be the emergency preparedness educational virtual environment. With this development, training health care professionals and emergency responders for sudden large-scale catastrophes such as natural disasters, bioterrorism attacks and outbreaks of infectious diseases has taken on a new life.

OTHER APPLICATIONS

Computer games have also found a number of therapeutic and social applications. For example, a simulation designed to employ computer game technology for lessening war trauma is available to a small number of patients at several sites, including the Veterans Administration Medical Center in Manhattan, the Naval Medical Center in San Diego, the Emory University School of Medicine in Atlanta and Walter Reed Army Medical Center in Washington. This simulation was created to treat Iraq war veterans who are suffering from post-traumatic stress disorder. The simulation uses a variety of images and sounds, such as a Blackhawk helicopter circling overhead, insurgents hiding on a roof and launching a rocket-propelled grenade, the animation of a violently shaking ground, and plumes of black smoke that cloud the vision (see Figure 8). In this type of exposure therapy, the patients are asked to confront their memories of a trauma by imagining and recounting it in detail. The immersive features and enhancements of virtual reality systems make this exposure therapy more effective than other treatments [56].

Second Life has also been used by psychologists to help abused children rediscover social skills. Similarly, a project called Live2give [58] was undertaken by nine adults with cerebral palsy. The nine group members share a single Second Life avatar. The objective of this project is to provide its members with a forum, in which they can share in the everyday personal interactions that most people take for granted and get to experience being around other people without being judged. Another project that has its own in-world island in Second Life is Brigadoon [59], an innovative online community for people dealing with Asperger’s Syndrome and Autism. In the same way as Live2give, this project’s goal is to try out the social interactions that for people with these medical conditions are so hard to experience in the real world.

CONCLUSIONS

Several applications of commercially available computer game engines for implementing virtual education and training environments were reviewed. While these systems are still in the early stages of their development, they have already provided us with glimpses into their tremendous potential for creating effective learning and training experiences in various fields, including education and student laboratories, medicine as well as disaster response and military training.

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