Chapter 5

Cyber and Cloud Technologies: Next Generation Technologies for Engineering Education

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This paper discusses the emergence of innovative technologies related to cyber tools and IT frameworks which hold the potential to impact engineering education substantially. These technologies include next generation Internet frameworks based on Cloud Technologies as well as 3D Virtual Prototyping and Haptic technologies. These cyber tools will enable sharing of sparse or less accessible resources, facilitate group based learning as well as provide avenues for learning to students with physical disabilities. The impact of such technologies on teaching engineering courses is discussed using specific discussions in manufacturing and space systems engineering. The challenges to the adoption of such technologies are also discussed.

INTRODUCTION

Information Technology (IT) is expected to impact engineering education in a substantial manner [1, 2]. With phenomenal breakthroughs in Information Technology (IT) including Virtual Reality (VR) technology, Cloud Computing and other Next Generation Internet networks, we are on the cusp of the next revolution which holds the potential to dramatically change the face of education. This paper presents an overview of some of these cyber technologies which have already impacted engineering education and hold the potential to continue to transform engineering education.

The discussions in this paper focus on two categories of these major technologies: (i) Next Generation Internet Networks, and (ii) Virtual Prototyping. We refer to these technologies collectively as ‘Information Centric Engineering’ (ICE) technologies. We also discuss some of the challenges associated with the adoption of such technologies at engineering programs as well as highlight the potential of such technologies to help students with physical disabilities. We also briefly outline the benefits of such approaches in the field of medical education.

Educators and researchers [2] have emphasized the fact that the recent knowledge revolution has transformed our jobs, our homes, our *lives*, and therefore *must* also transform our schools. Our information oriented global society is in the midst of the information revolution, which is radically changing the way we live, work and play. However, our educational approaches especially in science, technology, engineering, and mathematics (STEM) subjects have not taken advantage of this explosive growth in technology. In our national context, alarms have been sounded by leading agencies such as the National Research Council and National Academies of Science about the need for changes in our approach to STEM education.

The motivation to explore the use of Virtual Environments (which involves use of Virtual Reality technology) and other cyber technologies is based on several reports that indicate that the traditional textbook-chalkboard-lecture-homework-test approach has been observed to be ineffective for student learning ***in general***. According to [3], students are able to learn better by participating, acting, reacting, and reflecting, rather than by watching and listening. The primary beneficiaries will be students who will be able to learn better by using 3D virtual reality mediums, thus providing a strong foundation as they progress through various grade levels. Cyber technologies when coupled with Virtual Reality based learning environments enable the harnessing of distributed resources and hold the potential to facilitate sharing of computing and other resources. This becomes especially important when students in remote locations have to access learning materials including virtual or physical laboratories using advanced Internet technologies.

Virtual Learning Environments' (VLEs) [4-8] are cyber learning environments which support Virtual Reality technology. These environments can be built using Virtual Prototyping methods and can be viewed as subset within the universal set of virtual environments. VLEs provide a very intuitive learning environment which allows students to learn at their own pace as well as encourages a student's natural curiosity about engineering, science and other concepts. In today's context which increasingly involves use of digital technologies, students are at ease when using computer based gadgets such as an IPad or when playing video games. VLEs represent the next frontier in learning technologies and hold the potential to significantly impact engineering education.

In the following sections, we discuss advances in both networking and virtual prototyping technologies and their potential use to enrich engineering education.

NEXT GENERATION INTERNET TECHNOLOGIES AND FRAMEWORKS

While a large number of engineering and school educators use the Internet, an initiative involving another Internet termed the Internet2 has gone largely unnoticed. The Internet2, which is the successor of the Internet, is under development by a partnership involving U.S. universities, industry and the government. Internet2's original objective was to link universities, government and research laboratories for the purposes of collaboration, distance learning, research, health services and other applications that require high bandwidth between the distributed sites. Internet2 is intended for development and deployment of advanced network applications and technologies, including substantial increase in the bandwidth. This greater bandwidth will be especially useful in linking virtual environments at distributed sites. For example, a virtual environment to study engineering mechanics can be in the Stillwater, Oklahoma campus of Oklahoma State University; users at another university (say for example Texas A&M University or elsewhere) can access it through the Internet2 network. The greater bandwidth from Internet2 will enable better interactions among users at distributed sites who can be linked to collaborative virtual environments involving virtual tutors in the form of 'avatars'.

Recently, the US National Science Foundation (NSF) started a next generation Internet initiative called The Global Environment for Network Innovations (GENI) [9-12]. The GENI project initiative's goals focus on the design of the next generation of Internets including the deployment of ultra-high gigabit networks and cloud based technologies for various applications. Such networks especially facilitate high bandwidth graphics (such as virtual reality based 3D data as in our micro assembly context, camera monitoring videos during a manufacturing process, etc). GENI is being developed by the National Science Foundation (NSF) in collaboration with academia and industry. The Global Environment for Network Innovations (GENI) project also functions as a unique virtual laboratory for at-scale networking experimentation where new possibilities of future internets can explored. GENI type Internet frameworks hold the potential for engineering faculty worldwide to share teaching and lab resources especially those requiring ultrafast high-giga bit applications such as for accessing Virtual Reality based simulation and learning environments.

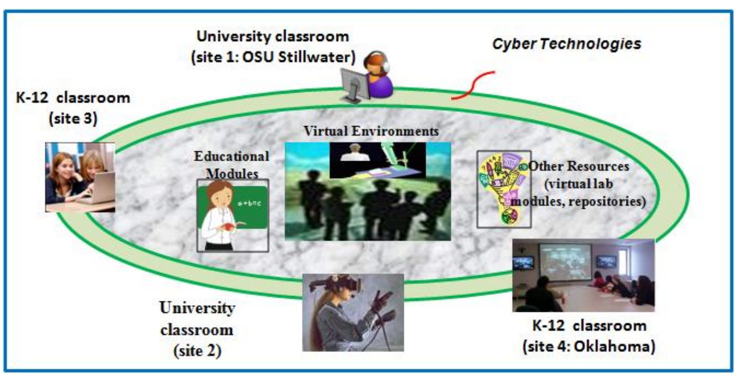

FIGURE 1
COLLABORATIVE LEARNING ENVIRONMENTS BASED ON CLOUD AND OTHER NEXT GENERATION CYBER TECHNOLOGIES

Cloud computing is one of the latest paradigms in IT which promises to transform cyber infrastructure into transparent, high performance, and reliable computing powerhouses that can address a wide set of needs in software industry, and education [9-12]. In a typical scenario involving engineering or educational contexts, there is a need to have access to data centers, data storage, a complicated software stack, and a team of experts to run them. If the target applications grow in number then the complexity in the maintenance of the application increases. If users have access to a "cloud", they can build their applications in the cloud and need not worry about the maintenance of the applications. This corresponds to reduced investment in computers, software and other tools 'in house'. A key benefit of using a cloud computing approach is that remote users with limited computing capabilities do not need any processors to access their applications or learning modules. A simple example of the power of cloud computing is the email application that most of us use when travelling (Gmail, yahoo, etc.). As long as the PC we are using (either at a hotel or at friend's home we are visiting) has Internet access and a browser, we are able to login and access our email files. The cloud infrastructure pulls in a variety of resources which allow us to read, respond and do other mundane activities.

In the context of education, the benefit of using a cloud computing approach is that geographically or remote users (with limited or no computing capabilities) can access a virtual suite of learning tools (software modules, tool kits, learning modules, etc.) through cloud technologies; as shown in Figure 1, this would allow K-12 schools and universities to share resources for educational activities especially related to classroom and lab based learning. Recently, we demonstrated the feasibility of adopting cloud computing approaches for engineering applications. Software modules for planning, simulation and analysis of micro assembly tasks were placed on a cloud linking Oklahoma State University and Ohio State University [12]. Remote users were able to access and interact with these virtual resources which involved developing assembly plans for various micron-sized part designs. Such collaborative infrastructure can not only benefit engineering educators but can also significantly impact educational activities in the field of medicine. Additional discussions are provided in the next section of this paper.

VIRTUAL REALITY AND VIRTUAL LEARNING ENVIRONMENTS

While Virtual Reality technology has been widely used for research purposes in various fields of engineering, its use in engineering education is fairly recent [12-19]. Only a limited number of universities [7] have reported use of Virtual Learning Environments [VLEs]. VLEs are virtual reality based environments created and used for educational and learning contexts. Such VLEs provide information rich learning contexts where students can virtual interact with target environments to understand various engineering, scientific and other principles.

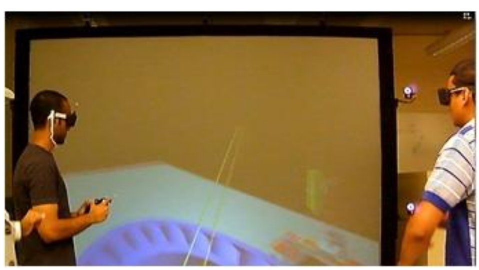

FIGURE 2
A VIRTUAL LEARNING ENVIRONMENT FOR LEARNING MICRO ASSEMBLY CONCEPTS

VLEs can be categorized into non-immersive, semi-immersive and fully immersive levels. Non-immersive VLEs are less expensive and can be run on a PC and other platforms. A semi-immersive VLE allows users to interact with 3D eyewear as well as controllers for navigation and exploration (Figure 2). A fully immersive VLE enables users to have a complete 360 degree stereo view; however, this is more expensive compared to the other two technology levels. Another class of VLEs incorporates the sense of touch through the use of haptic technologies. A haptic interface allows a student (or user) to feel the textures of a part as well as experience various forces coming into play. Such a capability substantially increases the level of engagement of a student who is learning both basic and advanced engineering concepts. This is useful at the university as well as K-12 levels. Having a haptic interface also enable children who have limited or no eyesight to understand and learn science and math concepts at an early age when learning development is critical. An example of a learning module can be a math module which enables a child to learn geometrical shapes using the sense of touch.

FIGURE 3
A HAPTIC DEVICE LINKED TO A VIRTUAL LEARNING ENVIRONMENT

In an engineering context, the same sense of touch opens up new avenues for students with limited or no vision as well as enables other students to experience forces that come into play in various engineering contexts. In emerging fields such as micro and nano manufacturing, such haptic interfaces can facilitate and enable students to experience interactive forces such as van der Waals forces (which can be scaled up as needed) to enhance the learning experience. By varying the parametric value of relevant factors (such as geometry or material properties), students can experiment using a 'what if' approach and learn relevant engineering concepts.

These technologies hold great potential in achieving a more inclusive teaching and learning environment where they can provide more educational opportunities in engineering and other fields for students with physical challenges.

Apart from engineering education, cyber technologies also have a significant potential to benefit medical fields related education. Expert surgeons and medical doctors can interact with medical students (residents) and nurses through thin clients as part of an extended Next Generation Internet infrastructure. In fields such as orthopedic surgery, a surgeon in one location (e.g.: El Paso, Texas) can interact with another surgeon or medical resident in another location (e.g.: San Francisco) using haptic and other interfaces. Recently (in March 2013), we demonstrated the feasibility of using cloud-based frameworks in medical education. In this demonstration, a surgeon (Dr. Pirela-Cruz) at the Texas Tech Health Sciences Center in El Paso (Texas) was able to interact with his staff through a haptic interface (Phantom™ device) linked to a virtual reality based simulation environment. This virtual environment was a simulator for orthopedic surgery. Such virtual environments are expected to become more popular as they allow residents and surgeons (with less experience) to learn interactively with and without the supervision of expert surgeons. Figure 3 provides a view of Dr. Pirela-Cruz interacting with a virtual environment for orthopedic surgery through the haptic interface; apart from using the haptic interfaced based simulation environment, the benefits of non-haptic based virtual environments were also demonstrated. A preliminary environment to introduce medical residents to a surgical process termed LISS Less Invasive Stabilization System (LISS) surgery was used to highlight the role of both virtual reality technologies as well as Internet technologies.

CHALLENGES IN THE ADOPTION OF CYBER AND VIRTUAL TECHNOLOGIES

While cyber and virtual technologies hold the potential to enhance and enrich student learning, there are several key challenges which need to be addressed to promote more wide-spread use. At a recently concluded NSF Workshop on Information Centric Engineering [7], some of the key challenges in adopting cyber and virtual technologies were discussed. These include the high initial cost, education and training, cost of maintenance, time to create the VLEs and lack of partnerships between academia and industry.

The development of VLEs is a time consuming process. One of the other key challenges is the significant expertise education and training required for faculty and engineers involved in the development of VLEs [4]. The team involved in such a process needs to include engineering faculty, pedagogical experts (from education), and software engineers or IT specialists. Depending on the complexity of the engineering topic being addressed, the creation of a VLE can range from six months to more than a year. However, once the VLE is developed, the impact on student learning can justify the investment in cost and time. At Oklahoma State University, several VLEs were introduced as part of two engineering courses (for senior and graduate students open to all engineering majors) [4]. One of these courses is 'IEM 4343/5343 Introduction to Micro Devices Assembly'; another is titled 'Information Based Manufacturing'. As part of the Micro Assembly course (IEM 4353/5343), students had difficulty understanding concepts related to various Genetic Operators including cross over, mutation and inversion. A semi-immersive environment was created where students were able to run a number of simulations using various sets of parent links for assembly sequence generation tasks. The environment randomly changed the sequences of the parents to provide a diverse variety of examples. For example, in one learning unit, the 3D environment focused on the formation of new child sequence from a single or multiple parent links. There were many benefits to this approach. Apart from an endless supply of demonstrations, students had the option of pausing a given simulation as and when necessary and repeat a specific step in the process or discuss questions related to the simulation in progress with the instructor. The most significant outcome was in the improvement in the student performance in understanding concepts in the modules in which the VLEs were introduced. Assessment data was collected for 92 students based on performance in quizzes, homework and exam questions. The initial assessment results indicated the following: Student performance in quizzes increased by 22%; student performance in homework and exams increased by 30% (in topics such as work cell design and genetic algorithms). A more detailed discussion of the outcomes can be found in [4]. Our assessment and analysis work is continuing in this and other engineering courses. This study is one of the first that has focused on the design and impact of such VLEs in engineering education. As discussed in [7], the use of VLEs holds significant potential in impacting learning in engineering education. Some of the challenges include lack of familiarity with Virtual Reality tools among engineering faculty, access to low cost technology (non immersive as opposed to semi or fully immersive) and the duration of time involved in building such VLEs.

Engineering faculty can address cost by adopting use of non-immersive technologies where students can interact with simulations running on a regular PC without the stereo vision capabilities. Haptic technology can also be incorporated (low end haptic devices can be in the range of $2,500).

Cloud computing is a recent networking technology which requires infrastructure improvement at engineering universities. As noted in [20], a cloud-based technology approach must be driven to address 2 crucial elements: serving the end user (students, faculty and administrators) as well as enable studying associated data to improve student performance and learning. While the IT revolution has transformed our society in general, the usual lament in engineering education is that there has not been a significant impact on education. A core part of this problem is that most faculty have adopted a ‘wait and see’ approach rather than implementing such technologies in their classroom. Significant impact on student learning (as demonstrated in the use of VLEs at Oklahoma State University) can be realized by introducing such technologies through pilot modules in identified courses. The educational context (with its potential on impacting student learning along with the challenge of adopting new technologies) presents an opportunity for faculty to collaborate, develop and introduce these technologies into the classroom. Interdisciplinary faculty with expertise in networks can team up with other engineering faculty to develop such cyber technology oriented environments.

The most significant difference will be in the improved accessibility by students to both classroom and lab based resources [21]. Students will be able to access learning resources (lab software, lecture materials, etc) from their dorm rooms, home or when travelling. For example, in [22], a pilot effort involves creating a virtual fluid laboratory which can be accessed through the cloud. The current approach involving students coming to various engineering labs on campus to use software and tools limits the accessibility of such tools from other locations. Another key benefit is that the cost of maintaining computers along with routine software upgrades can be alleviated by using cloud technologies.

CONCLUSION

In this paper, an overview of Next Generation cyber and virtual engineering tools which can substantially impact engineering education is provided. A discussion of Cloud and GENI related frameworks were provided. In the context of Virtual Learning technologies, the potential of using Virtual Reality technologies to develop VLEs for engineering and K-12 programs were outlined. The adoption of haptic technologies and their impact on increasing access to engineering and science education was also elaborated. This paper was concluded with a discussion of some of the key challenges in adoption of such technologies in engineering education.

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