Virtual Reality in Engineering Education: A CIM Case Study

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Abstract: Instructors in technical schools, polytechnics, and universities of technology must continually help students find the links between theory and practice. Students often don't recognize the links among the various subjects they study, or the links among the various tasks they perform as they study. It is well known that students learn best by doing. This is especially true in science education where important concepts within the curriculum are acquired through experimentation and manipulation. Virtual Reality (VR) helps instructors motivate students to discover those essential links in a fresh, exciting educational environment which develops well-rounded thinking and real-world behaviors. VR has been shown to be an effective way of teaching difficult concepts to learners. VR system has been described in this paper. Applications of VR in education are discussed and a case study is given for the Computer Integrated Manufacturing (CIM) course in Eastern Mediterranean University Mechanical Engineering Department.

Introduction:

The last decade has been witness to significant change across broad areas of our physical, social and cultural systems. These changes are clearly reflected in the growth and development of computer technology with applications in such diverse areas as credit cards, mobile phones, cars and cameras as well as the ubiquitous PC.

Education has also had to accommodate change reflected in an ever-growing student population, which occupy places on existing or newly developed courses covering a very broad range of subject areas.

These changes in the educational system and the provision it makes have often to be achieved with little if any rise in institutional costs or resources. Given that a main contributor to the cost overhead are the teachers educational institutions employ, the number of staff employed has not risen, indeed, in some cases there has even been a reduction.

The ramifications of these changes are increasing the student/staff ration, reduction in student contact hours which, if conventional educational practices persist, would lead to a diminishing quality in the learning experience offered.

Such pressures on the educational system have come at a time when the cost of computing equipment has been reducing whilst the capability increases leading to a growing interest in Computer Aided Learning and Teaching (CAL and CAT) systems employing a variety of approaches.

Lockard, Abrams, and Many (1994) identified two general groups of CAL/CAT application systems: Type 1 involved using computer resources to do activities carried out at present without the aid of computers whilst Type 2 applications involved using computers to enable teaching and learning in ways that had not been possible employing conventional teaching approaches.

Type 1 applications do not generally change the teaching strategy but do assist in making learning independent as well as helping to reduce the need for direct teacher involvement.

Whilst these approaches may assist in alleviating problems associated with direct contact hours, they may not contribute much to the quality of the learning experience.

With a growing capability in computer technology, new techniques and approaches to learning have and are being developed to enable provision of a learning experience not previously possible. This has given rise to the applications identified as Type 2 into which the system described in this paper may be classified.

Engineering educators need to develop graduates with attributes and abilities previously not considered core to their professional practice. Developments in technology and science provide new tools and approaches to facilitate better learning-teaching environment.

Virtual Reality is a powerful computer based tool for education since people comprehend images much faster than they grasp lines of text or columns of numbers. Participation is critical to learning and VR offers multi-sensory immersive environments that engage students and allow them visualize information.

Virtual Reality:
Virtual Reality (VR) systems have the potential to allow learners to discover and experience objects and phenomena in ways that they cannot do in real life.

The aim of VR is to achieve a maximum sense of reality for the user within a computer generated environment. In a unique way, a sense of presence has to be established between the user and the computer.

At present, VR systems can be categorized into four different set-ups as: Desktop system, Wide-screen projection system, Immersive CAVE system, and Immersive VR system using head-mounted displays (HMDs).

Desktop VR resembles the typical human–computer interaction (HCI) most closely. It uses the monitor as the viewing device, and a mouse, keyboard or glove for interaction. Together with a computer, which is capable of displaying the virtual model in real time, and a suitable VR software package, this arrangement often forms the entry system to VR applications.

Wide-screen projection is used to increase the field of view (FOV) from 20–30° with a monitor to over 100°, or if multiple projection screens are used, the projection can fill the entire viewing area.

A set-up with multiple projection, usually three walls and the floor, is called a CAVE and is by far the most expensive VR platform. Shutter glasses, which provide stereo vision, complete this very effective immersive VR system.

VR using an HMD offers a much more affordable immersive system. Two displays are mounted into a helmet, which provides the user with a stereoscopic image of the model. The HMD is position tracked in real time and the images are updated according to the user's position and orientation. A keyboard and mouse cannot be used because they are invisible to the user, but a 6 degree of freedom (6 DOF) interactive device is used instead.

There are three major categories for the available VR software as: Toolkits, Program Languages, and Authoring systems.

Toolkits are programming libraries, generally for C or C++ that provides set of functions with which a skilled programmer can create VR applications.

Program Languages are specially developed programming languages for 2-D and 3-D VR applications, such as VRML and Java 3D.

Authoring Systems are complete programs with graphical interfaces for creating worlds without resorting to detailed programming. These usually include some sort of scripting language in which to describe complex actions, so they are not really non-programming, just much simpler programming. The programming libraries are generally more flexible and have faster renders than the authoring systems, but you must be a very skilled programmer to use them.

Regardless of the VR type and VR system, the following advantages can be obtained by using VR:
1. They provide a sense of scale, from motion parallax and the stereo view.
2. There is ease of interaction with complex components using 3D input devices.
3. Skill acquisition is improved.
4. It is a unique way to study complex interactions.
5. Improved understanding is gained through direct interaction.

The simplest way for creating VR is to use VR Toolkit and the cheapest type is the Desktop VR, where user may only need better graphical card then he/she already have.

Applications of VR in Education:
Recent developments in VR have made it a more advanced computer technology, and attracted increasing amounts of attention among researchers in many educational disciplines.

As the technologies of virtual reality evolve, the applications of VR become literally unlimited. It is assumed that VR will reshape the interface between people and information technology by offering new ways for the communication of information, the visualization of processes, and the creative expression of ideas.

Note that a virtual environment can represent any three-dimensional world that is either real or abstract. This includes real systems like buildings, landscapes, underwater shipwrecks, spacecrafts, archaeological excavation sites, human anatomy, sculptures, crime scene reconstructions, solar systems, and so on.

Of special interest is the visual and sensual representation of abstract systems like magnetic fields, turbulent flow structures, molecular models, mathematical systems, auditorium acoustics, stock market behavior, population densities, information flows, and any other conceivable system including artistic and creative work of abstract nature.

VR technology has been widely proposed as a major technological advance that can offer significant support for education. There are several ways in which VR technology is expected to facilitate learning. One of its unique capabilities is the ability to allow students to visualize abstract concepts, to observe events at atomic or planetary scales, and to visit environments and interact with events that distance, time, or safety factors make unavailable.

The US Navy uses flight simulators to help train pilots for general navigation as well as special assignments. Battlefield simulations have been developed using real data from Desert Storm. These types of simulations can be used for training as well as planning. Distributed simulations allow users in remote locations to participate in the same environment. Training tools can also be used for common citizens. For example virtual cars could be used for driver's education classes reducing the expense of cars and insurance and perhaps minimizing costly accidents by inexperienced drivers.

The types of activities supported by this capability facilitate current educational thinking that students are better able to master, retain, and generalize new knowledge when they are actively involved in constructing that knowledge in a learning-by-doing situation.

VR offers tools for increased student participation. Classroom activities will use VR tools for hands-on learning, group projects and discussions, field trips, and concept visualization (Bricken, 1991). Traditional teaching involved text, oral and screen-based presentations which do not use a human's full capacity to learn. VR allows natural interaction with information. Instead of reading about foreign places or watching a videotaped program, students can explore new worlds such as foreign countries, ancient times or the human body. A current VR program for seventh-graders lets students act as part of algebra equations (Bylinsky, 1991). VR offers a learning experience that many children and adults find interesting, thus giving motivation to learn.

The potential of VR technology for supporting education is widely recognized. Several programs designed to introduce large numbers of students and teachers to the technology have been established, a number of academic institutions have developed research programs to investigate key issues, and some public schools are evaluating the technology.

Telepresense offers remote learning with virtual classrooms. Students are not limited to classes that are taught at their school, in their town, or even in their nation. Teleconferencing has allowed for persons at different sites to form a virtual classroom with active class discussions. Telepresense has also allowed for remote students to work together on group projects which may be an important part of class participation and learning.

Virtual Reality provides the tools to visualize and manipulate abstract information, thus making it easier to understand. For example flows of power and data communications traffic can be visualized dynamically in three dimensions. NASA has developed a virtual wind tunnel that allows the participant to use hand gestures to navigate around the virtual aircraft and view the airflows. Eastman Kodak engineers gained new insights using a 3D model showing the interactions of heat, temperature and pressure. Virtual environments can allow participants to experiment with physics concepts such as a virtual physics lab that allows students to control gravity, friction and time.

A CIM Case Study:

The global market for manufacturers has changed rapidly in recent years and has become very competitive. In such competitive environment, it is very difficult for enterprises to continue with their functions. Then they search for new approaches from a wide spectrum such as Computer Integrated Manufacturing (CIM) and Flexible Manufacturing Systems (FMS) for manufacturing technology.

To compete in rapidly changing markets, enterprises have turned increasingly to automation in their quest to produce parts faster and with greater consistency and conformity to quality specifications. Automation alternatives like CIM, has been crucial and instrumental allowing enterprises to reduce lead-time, and increase flexibility and reliability.

In the past few years, world industry has changed its approach to manufacturing within the development and use of CIM Systems. There has been an emphasis on the integration of engineering, design, manufacturing analysis, and business management, in an attempt to create an enterprise wide, co-ordinate of manufacturing system.

The use of CIM reduces cost by 15-30%, reduces the in-shop time of a part by 30-60%, increases productivity by 40-70%, reduces scrap by 20-50%, and provides many other benefits.

The developments in the industry forces institutions and universities to improve their curriculums and prepare the students to their new lives as ready as possible. To this extend it seems CIM education is mandatory for both Industrial and Mechanical Engineering Departments. Nowadays it can be seen from the curriculum of well known universities through the world that CIM is one of the important topic of both Mechanical and Industrial Engineering education.

CIM is a course that practical study is very important. Teachers need laboratory in order to show some real cases to the students. Robot is one of the well known elements of CIM systems. A computer is needed to load and unload the programs of the robot and special software is also found on the computer to teach robot tasks. Students have difficulties to understand task teaching to the robot. Although only one simple example is given here, there are many problems in the student's minds where core of these problems and questions are visualization. Since lots of theoretical science is loaded to the students they would like to see some real examples and applications.

CIM laboratories are very expensive. The reason is, elements of CIM systems, integration of CIM system, and controller of the system is cost too much. There are some rich universities that they adopt CIM laboratories but many universities have difficulties of adopting CIM laboratories.

(DENFORD Company) has developed a VR CIM System as seen in Figure 1, replicates a full industrial CIM System for training students and industry. The virtual worlds show all the elements of a CIM system, many of which can be found in educational and training establishments around the world, including CNC mills & lathes, robots, conveyor, ASRS, CMM, AGV and vision system. The VR CIM provides a low-cost introduction to Computer Integrated Manufacturing; and is available in three levels, CIM Viewer, CIM Manual Control and CIM Host Control.

Figure 1

The VR CIM solution of DENFORD has a good acceptance all around the world universities. With the help of the VR CIM, students are able to visualize many things as they were in real industry. They can react with objects, interact with the environment, and immerse to the CIM environment as much as they like.

But it is clear from the experience that even VR CIM solution of DENFORD is dedicated that is teachers were not able to educate everything else they prefer to the students.

Eastern Mediterranean University has both Industrial and Mechanical Engineering Departments. CIM is technical elective course in both of the departments. Mechanical Engineering Department is trying to develop their own CIM laboratory with their own staff and resources. It seems it will take years to complete it. On the other hand Industrial Engineering Department has started to construct their CIM laboratory. Since the cost is too high it is found better to construct it modular. That is to buy some part this year, another part next year etc. Still CIM Laboratory is not finished.

Within this conditions, in order to highly educate current students both of the departments have VRCIM solutions. It is not fare to cause the current students to have lack of experience. In the CIM lecture students uses both VRCIM solutions and makes experience with both of the laboratories of not complete.

As it is described below even commercial VRCIM solutions are dedicated. That's why a new VR CIM solution is completed in Mechanical Engineering Department. As experts of CIM education a new VR CIM solution as seen in figure 2, is arranged in a way that deficiencies of current solution in hand are solved.

Figure 2

Superscape **V**irtual **R**eality **T**oolkit (VRT) is used to create new VR CIM tool for CIM education. Superscape (VRT™) is a complete 3D authoring studio for PCs that have been used to create the new VR CIM world. It enables the users to create interactive 3D worlds that may even be published on the Internet using Superscape's Viscape, or displayed on the standalone visualizes platform.

VRT consists of an integrated set of editors (World Editor, Shape Editor, Sound Editor, Layout Editor, Keyboard Editor, and Resource Editor) that enables the user to work on different steps of VR world constructions.

To be able to create realistic worlds, textures and sounds may be added to objects in the world, and different lighting setups should be done within the World Editor. Superscape Control Language (SCL), which is based on the popular 'C' language, will be used to assign behaviors to object in the world and perform complex actions.

All basic movement and interaction with Superscape VR worlds and moving around the objects can be made from the mouse and keyboard, although a peripheral proportional device (such as a joystick) is also possible.

VR prototype of a training system in six different rooms in different levels of manufacturing hierarchy have been prepared for being used in training and educating the students in order to give a sound base in CIM systems.

Students are supposed to follow the instructions that have been prepared through the user interface in the form of tutorials for each room about the equipments and how to implement the different operations and tasks within each machine. They will be able to manipulate and move the different parts of the equipments and see how a simple operation or a task can be selected and performed in an automated machine.

User will be able to control a workstation that consist of several machines and manage the equipments to produce a product or a series of different products in different methods. They will get familiarize with the scheduling and the importance of sequences in the production process. Also it can be seen that how different machines will communicate with each other in order to realize which operation under what conditions in which order should be performed to be able to perform produce a product. And finally it can be inferred that how an automated system that is the integration of several equipments, can be used for producing different products and reduce the part-lead time.

Conclusion:

There are many potential high-payoff areas for research and development of VR technology for education and training. VR needs to be developed as an integral part of the educational and training process, implemented alongside other traditional and non-traditional tools.

It can be used for exploration and for training practical skills, technical skills, operations, maintenance and academic concerns. Teachers and trainers need to be exposed to VR in multiple ways so that they can begin preparing themselves and their institutions for future changes.

Integrated scenarios for an assortment of manufacturing environments and educational areas need to be developed to give educators and trainers a better view of the strengths and weaknesses of these environments.

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