VIRTUAL REALITY AND ENGINEERING

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Abstract The importance of using Virtual Reality Technology as a means of designing, visualising and simulating various environments is growing and the creation of virtual environment is only limited to the imagination of the virtual environment designer. A picture is worth a thousand words, according to an old Chinese proverb; if this is so, a graphical animation reduces design cost and increases human productivity. Virtual Reality (VR) is the latest and most powerful interface between computers and humans. VR is an interactive, three-dimensional (3D), multisensory experience which immerses the individual in a computer simulated world. It is a powerful medium for communication and visualisation. Visual instruction, active learning, multiple scenarios and involvement can all be enhanced. The paper tries to highlight importance of Virtual Reality (VR) in Engineering and use of VR in present research activities in the world including least developing countries like Bangladesh.

Keywords: Virtual Reality, Virtual Environment, Engineering, Design, and Prototyping.

INTRODUCTION

Virtual Reality (VR) allows a person to experience phenomena that appear to be real but exist only in the computer. Thus, the user (or designer) "feel" immersed, as if he or she is actually "in" the three-dimensional space [8]. Using VR based systems, a user or designer can visualise a final product, assemblies, sub-assemblies or components. The moving objects and all in-between situations of the simulated world can be viewed with the presentation techniques of VR, like stereo viewing, fly by or walkthrough. Similarly a newly developed process can be seen in computer screen first, when this is just finished in design stage.

Most engineering students learn best from learning processes which are sensory, visual, inductive, and active, while most lectures tend to be intuitive, verbal, deductive, and passive in nature. Though these days it has become a common practice to talk about the millennium, or atleast of the 21st century, the rapid and unprecedented development of 80s and 90s of the 20th century has made it prohibitively impossible to foresee the development even of this 21st century. Recent advances in the computational and communication capabilities of computers and their associated infrastructure offer great promise for supporting continual improvements in all aspects of undergraduate education and industrial training. These advances also underscore the need for credible research into the practical benefits and limitations of teaching and learning in settings, enhanced by information technology. Information technology tools can enable students to visualize and experiment with complex, real-world scientific problems, promoting exploration and enquiry based modes of learning. They also enable collaboration, interactive learning, and new pedagogical approaches that changes the way in which students and faculty interact. One of the promising information technology tools is the virtual reality. Since it's development in late 1950s, virtual reality (VR) has been a useful tool in various fields to simulate different situations or technology is available to create applications in many fields and the designer's imagination should take advantage of this technology.

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The potential of using VR in the training sector is enormous as can be seen from the early days of the NASA flight simulator to recent advancements of using VR to train surgeons in the medical profession. This paper covers concepts of virtual reality and virtual

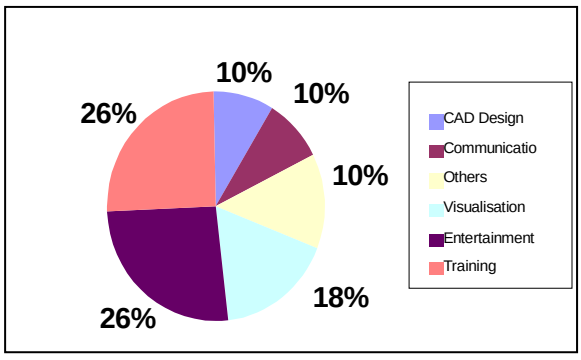

Fig. 1 Virtual reality Discipline Segments (Iqbal,M. 2000)

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environment, different types of virtual reality systems, application of VR in engineering, use of VR in Bangladesh, discussion on present research progress and lastly conclusion.

CONCEPT OF VIRTUAL REALITY AND VIRTUAL ENVIRONMENT

Virtual Environments are made up of 3-D graphical images that are generated with the intention of interaction between the user and the objects in that environment.

The term virtual environment (VE) describes a computer-based generation of an intuitive perceivable and experienceable scene of a natural or abstract environment (Iqbal, M., 2000). VE applications will contribute to enhancing the qualities of human-computer interaction, the importance of which, in view of increasing complex information and communication applications, is constantly rising. VE technologies are more able than conventional computer applications to influence the thinking and behaviour of people and to come to grips with social processes. Consequently, VE applications are not only challenging technical and social concepts, but also philosophical ideas. The concept of Virtual Environment came from Virtual Reality originated in the 1960's. At that time, however, because of limited computer capacity, one was only able to create primitive geometric objects and environments. The recent surge in VR technologies gives a new impetus to the development of new and better training solution. First VE applications were employed under the U.S. military and at NASA, who tested telepresence for the purpose of remote control tasks in space. The U.S. military was using flight simulators with computer-generated graphics to train its pilots. The availability of powerful graphic computers led towards a technological push and the research in diverse application fields within science, industry, and entertainment. As a result, the commercial development of VE applications started during the 1980s. Today, both, science and industry commit themselves worldwide to the further development and expansion of VE systems.

In the 1970's. Hollywood started to realize the power of VR in the film industry due to it's potential to create extraordinary Visual Scenarios. Films such as 'Star Wars', followed by 'Terminator' and 'Jurassic Park' are just some of the films that benefited immensely from VR and computer graphics in general. Recently Pentagon has conducted a Virtual Nuclear War Game to predict its consequence. The capabilities to put the ergonomic knowledge into practice, efficient computer-supported methods of integrated work system design are being investigated, developed, and used, which make new dimensions of application possible. Essential characteristics of these methods, which are based on virtual environment technologies, are the three-dimensional modeling and simulation of virtual objects and situations, where the users are intensively and multisensorily integrated by means of intuitive, real time-oriented intersection modes (Iqbal, M., 2000.

LITERATURE ON APPLICATION OF VIRTUAL REALITY

Many theoretical studies and research work have produced methodologies and basic software techniques which are at a level of refinement that is required for subsequent development of virtual reality in design, prototyping, assembly, virtual training, engineering analysis and factory modeling in virtual environment are briefly outlined as follows:

Stone (Stone R. J. 1991) describes the advantages of computer aided design in which both the designer and the end user can observe, manipulate computer generated object. Similarly Haney and Romero (Gibson et al, 1993) envisage Ves-which enables designers and developers to actually 'see' the piece or system being designed and the manner in which it functions in operational environments. On similar lines Kalawsky (R.J.Hallands 1994) proposed virtual environments to prototype product designs in order to remove design and development risks early in the manufacturing life cycle. B. Bahr and G. Li (Encarnaca O.J., et al, 1994) reported examining motion behaviour of an existing dump truck in a virtual environment, the motion behaviour of the dump truck can be easily and effectively evaluated and verified. Thus, design change can be performed before actual production. The period of the system design cycle can be shortened and thus reducing production cost. Gibson (Karacali, R. Bell 1994) used the virtual reality tool (VIRART linked to CAD system) to provide complimentary technology to rapid prototyping to control software in a form that models the real life in design and manufacturing.

Holland's (O. Karacali, 1995) searched possible solutions to an information management system to connect to Virtual Reality application. Encarnacao (O, Karacali, 1994) gave an excellent survey on European efforts related to virtual reality and its application. Research on virtual reality is now being developed to include scientific visualisation (Dietz et al 1995), graphical user interface (Grebner et al, 1995) and object-oriented programming language (Oli, Odegard, 1995). Recent developments in CAD/CAM systems that employ computer simulation for designers to analyse products must also be included.

Automotive manufacturers like Ford and Mercedes-Benz (Aukstakaluis, 1992), are examining the VR technology for the virtual prototyping of cars. Oli Odegard, in his paper (Sherrard et al 1994) cited about VR application in architecture/design and industrial product areas as 09% and 08% in Nordic countries respectively. Volvo has been using VR in their interior design processing of cars. Equipped with an HMD

(Head Mounted Device) the designer can sit in a model of the car and try out a proposed layout of the panels and instruments before it is implemented. MIT's CAD lab has developed the 3Draw-package (Tsung-pin yeh et al, 1995) which allows the users to sketch in 3D. London based twelve firms pull together to form Europe's leading virtual reality research centres, which applied computer based simulation and industrial design with 3D modeling projects called Virtual Reality and Simulation (VRS) (Painter,B. ,1995). Many companies use VRS and work together with the Advanced Robotics Center (ARR) to improve the aspects of the virtual reality models. These companies include Roll-Royce, Nirex, Vicker Ship building and Engineering, ICI Chemicals and Polymers and British Nuclear Fuels. These companies use VRS and ARR to run impact studies, as well as vary other tests. One example is when Vickers used it for 3D walk through models of nuclear and diesel submarines (Painter,B. ,1995).. Tsung-Pin Yeh and Judy M. Vance (Sullivan O' Damien, 1998) developed a technique to do sensitivity analysis and design optimization process in a virtual environment A simple cantilever beam with homogeneous material property was tested to investigate the feasibility of interactive design sensitivity and optimization in a virtual environment. Judy M. Vance (Tuikka, T. et al, 1997) developed a program, called Spare VR that allow four–bar spherical mechanism design in a virtual environment. Spherical mechanisms are a sub-class of the more general category of spatial mechanisms. Even though virtual environment technologies are still difficult and expensive to use, people are doing real work. Virtual Manufacturing (VM) provides the engineer with the capability to " Manufacture in the computer". Manufacturing environments may be simulated in a 3D virtual environment. Practical and efficient may be simulated in a 3D virtual environment. Practical and efficient use of VM technology is a necessary step as more and more emphasis is placed on zero defects manufacturing (Vance Judy M., 1996). In essence, VM will ultimately provide a modelling and simulation environment so powerful that the fabrication/assembly of any product, including the associated manufacturing processes, will be simulated in the computer. It is expected that with the use of VM, the complete manufacturing process will be visual before the product is actually put into production. Manufacturing, in this case, is taken to encompass issues relating to maintenance and training as well as the actual creation of parts and the assembly of systems. These example actual real world systems, not simply speculative fantasies.The assembly of aircraft is a highly complex task, which is difficult to automate. Many of the skills required demand dexterity not easily accomplished by robots. In addition airplays consist of many small lots size parts and reprogramming robots for these quantities is an expensive prospect. To quote from Caudell and Mizell's paper "Someone once said that a Boeing 747 is not really an aeroplane, but five million parts flying in close formation."

Researchers at Caterpillar Inc. (Mourant et al, 1997) have used VR to improve the design process for heavy equipment. Dave Stevenson and John Bettner engineers with Caterpillar in collaboration with the staff of NCSA (National Centre for Supercomputing Applications) have put together a system, which allows them to quickly prototype wheel loader and backhoe loader designs. In particular the team is able to perform visibility assessment of the new design. Engineers put on a helmet-mounted display and have a full 360 degrees of vision to see how the environment looks and to evaluate obstructions. The engineers can "operate" the equipment and evaluate visual obstructions in a natural manner without having to build a physical prototype. This image from the Virtual Backhoe project illustrates an "operator" driving the virtual equipment at the NCSA VR lab. The Caterpillar team was awarded the 1993 NCSA Industrial Challenge Award for VR Use. "This technology allows us to dramatically shorten the amount of time it takes to analyse a new design concept and incorporate it into our production process," design Engineer Dave Stevenson said ((Mourant et al), 1997) "It also represents a sizeable cost savings because we aren't having to build prototype machines or make last-minute design changes." He said it takes six to nine months to build full-scale models and design changes using conventional design methods. However, using the virtual reality approach, designs usually can be evaluated in less than one month. The Ford automotive company (Mourant et al, 1997) has set up a development division called Ford Alpha Simultaneous Engineering. This development organization is trying to evaluate the use of VR for automotive assembly. According to Jim Merner, manager of the VR project, they are evaluating process installation feasibility. The vehicle parts are represented in a CAD system. The CAD file is transferred to the system with the VR equipment. A user then manipulates the virtual part and attempts to assemble it into the virtual vehicle. The equipment used for the VR experiments are a VPL eye phone and data glove running of a Silicon Graphics computer. The user puts all the equipment on and attempts the part insertion. The system checks for interference and collision between the part and the vehicle. The hope is to use the VR set-up to evaluate the human ergonomics of various assembly operations. One of the most essential benefits of the virtual prototyping concept is that it can offer a visualisation of an artifact to mediate an idea of design or reflect the idea (Mourant et al, 1997). When a new product is introduced various ergonomic and fundamental design effects have to be given serious consideration. VR makes use of a form of "digital clay" to create these prototype. Lifting operations are among the most difficult and dangerous tasks performed on the shop floor. In reality crane operation requires 40 hours of training for certification, and more importantly, experience to master. Using a virtual environment to simulate crane-lifting operations will not only improve crane operation techniques but also reduce injuries and deaths caused each year by

crane accident. H, Lee Keun and Vance, Judy M., (Scott Chester.ac.uk.) designed software to train and retrain workers in virtual environment. This software particularly focused on training workers to manipulate a robot using TELEGRIP, Deneb Software Company. P.L. Chong and A.M.S. Hamouda (Manery. n.tt.ac.uk.) developed an Internet based virtual laboratory for simulation of tensile testing process on Instron 1342 machine for distance learning purpose. The main aim of the project was to reduce the testing cost and to standardise the testing performed by distance learning students. C.F. Cheung and W.B. Lee (Jane K. C. Et al, 1993) developed software, which allows for the simulation and the optimisation of optics design under a preconditioned computer environment. The virtual machining module makes use of the optics design parameters together with the machine characteristics data to simulate the tool path and the surface topography of the workpeice. Besides, the selection of optimum cutting process parameters and machine capability evaluation can also be done in this module. The form and the surface roughness of the workpeice are inspected by the virtual inspection module, which simulates the measured surface roughness profile and hence determines the surface roughness of the machined surface

Plenty of literature exists on the origin of VR system and its application in different fields, like ergonomic analysis, assembly modeling, computational analysis, etc. In case of factory layout modeling and analyse, a few literatures are available. It's because research in this area is new compare to other areas like prototyping, games, military training, astronaut training, and creation of science fiction movies, surgery, ship, submarine and aircraft manufacture. The main reason is the research funding according to importance. Research in factory planning in virtual environment and virtual manufacturing started after 90s. People are doing research in industrial areas but keeps secrecy of the research due to competitions.John, R. Wilson (Iqbal, M., 2000) reported about the Virtual Reality Application Research Team VIRART which was established in 1991 in the department of Manufacturing Engineering and Operations Management at the University of Nottingham, England. This organisation has worked with UK industrial companies and the Health and Safety Executive to build and test VR worlds, which simulate hazardous conditions that an operator may be subjected to. VIRART have also built Virtual Environments which illustrate the use of a good plant layout in which the user can travel through the virtual plant, interact with the facilities and observe the surroundings before the plant is built. The use of VR will prove to be a valuable aid to industrial and manufacturing engineers in relation to plant layout in the future. Iqbal, M. in his thesis mentioned about creation of a virtual factory to investigate the role of visualisation and virtual reality could play in the decision making process when manufacturers are faced with investing in new technology (Iqbal, M., 2000) . Holland, R. J. and More, N. cited some examples of VR software use in modelling a car factory in virtual environment (Hollands , R.J. et al 1998).

ADVANTAGES OF USING VIRTUAL REALITY IN ENGINEERING

Using VR for product design could provide design flexibility by allowing the exploration of various options and the opportunities to play "What if " experiences where mistakes are less expensive. Significant cost saving could be achieved in system development and production because many of the problems would be identified and corrected before the actual physical product construction.

(i) Engineering training in Virtual Environment will help in reducing actual cost of buying real equipment/machine thus giving a safety training to operator / student in Engineering education (ii) Reach studies and ergonomic assessments can be performed in the virtual environment (iii) Virtual Reality gives more precise planning (iv) Virtual reality has the provision for exchange of knowledge among different experts in the planning team (v) Various influential factors, workplace safety, accessibility and production tools can be visualized using VR. (vi) Planning and verification of Production/ manufacturing process ca be achieved by using VR (vii) Determination of production sequence can be determined using VR (viii) Using VR can do analysing of different alternatives of production and assembly.

USE OF VIRTUAL REALITY IN BANGLADESH

More recently, advances in computer technology have lead to many high – quality computer based educational tools, including interactive computer modules, multimedia presentations, and process simulators. Most of these computer programs, however, still leave the student as an external observer being presented with information, with only limited active participation. Virtual Reality, on the other hand, promises to pull students inside the simulations, to immerse them totally in educational experiences not otherwise possible. VR technology may be represented in a virtual environment. Technicians and students may learn about a particular machine by using a VR machine. VR machines have the advantages of not requiring the actual machine or equipment associated with operating cost. There are also certain experiences and viewpoints, which only virtual reality can provide. VR technology in various forms has been used for many years in the development of training systems in Europe and America especially for military applications like flight trainers, equipment operating training, simulating surgical techniques, and maintenance training. The future of training is destined to become an interactive process, as the student may

participate in the learning experience actively and not passively.

In Bangladesh there are several government and private controlled universities, four BITS (Bangladesh Institute of Technology) and a number of private computer training institutes. But only two universities offer Virtual Reality as one of the undergraduate courses. But only two universities namely Islamic University, Khustia and Shahjalal University of Science and Technology, Sylhet offers Virtual Reality courses. A laboratory for Virtual Reality is under development for Industrial and Production Engineering Department of Shahjalal University of Science and Technology situated at Sylhet At the same time Dept. of Industrial and Production Engineering, Shahjalal University of Science and Technology, Sylhet is doing research on development of virtual engineering training center for engineering students and technicians for learning and training purpose. So the concept of Virtual reality has come to one of the third world countries like Bangladesh.

Using VR a bridge can be built virtually. Load and structural design can be analysed before building the real one with defects. Thus civil engineering student can learn designing virtually a bridge, tall buildings, culverts, flyovers and tunnels etc. In addition to that, strength of materials and fluid mechanics can be studied using Finite Element and Fluid dynamics software. Civil Engineering dept of BUET, Dhaka can use commercially available software for bridge design and analysis. The software could be used for undergraduate engineering studies. Human Factors Engineering or Ergonomics is taught in the undergraduate courses of Industrial and Production Engineering Department of Shahjalal University of Science and Technology, Sylhet. As most engineering application of VR at present time are focused on the development of virtual prototypes, ergonomic assessments of visibility, reachability, clearance, comfort and aesthetics is generally performed on a physical prototype. If the same kind of assessment can be performed on a virtual prototype, significant savings will be realised in the design of new machines. Software under the name 'JACK' is commercially available for teaching undergraduate student to implement the concept of Human Factors Engineering or Ergonomics in designing different types of products and industrial workstations. Also software for different mechanism design, virtual training for machine operation, analysis of Automobile car frame in virtual frame are available in the software market. Nowadays CAI (Computer Aided Instruction) concept is used in IT training for teaching and learning processes. CAI is a technology expanding to assist in the teaching and learning process, which a student undergoes. CAI is also known as Computer Assisted Instruction. This form of teaching instruction is growing rapidly and is used in such areas as computer visualisation of complex objects. Information can be represented to the student in text or multimedia formats such as photographs, simulation and speech. Exploration and manipulation of various simulated environments can be accomplished with CAI by using a model to experience reactions from various student inputs. Electrical and electronics engineering students can learn virtually about circuit design and other phenomena of electrical and electronics engineering using different software which have visual advantages. Using VR based systems, a user or designer can visualise a final product, assemblies, sub-assemblies or components. The moving objects and all in-between situations of the simulated world can be viewed with the presentation techniques of VR, like stereo viewing, fly by or walkthrough. Similarly a newly developed process can be seen in computer screen first, when this is just finished in design stage. In this way, the VR simulated system can often help to find potential mistakes in the initial stages and correct as many discrepancies as possible before the expensive real model is actually built.

The graphic-based benefits:

- Provides motivation.
- Can more accurately illustrate some features, processes, etc. than by other means. Allows extreme close-up examination of an object. Allows observation from a great distance.
- Allows the disabled to participate in an experiment or learning environment when they can not do so otherwise.
- Gives the opportunities for insight.
- Allows the learner to proceed through an experience at his or her own pace.
- Allows the learner to proceed through the experience during any time not fixed by class time. Provides experience with new technologies through actual use. Requires interaction. Allows students to experiment with different personalities.

PRESENT RESEARCH

At present Dept. of Industrial and Production Engineering, SUST Sylhet, has taken a project on Engineering personnel (technicians, teacher and students) training program using the VR desktop system. Virtual workshop machines are to be designed and animated in virtual workshop environment.

Objectives of the present project are:

The use of 3D Studio MAX software to model a Workshop (Machine Shop) in 3D environment and applicability of the 3D studio MAX system to assess it's user friendliness to assist the design and planning of workshop facilities in 3D environment

*Rapid prototyping through design and test facilities.

modeling, dimensioning, reforming, orienting and colouring.

*Walk through around the workshop floor with rapid switching of viewing points.

*Visualisation of the workshop using viewpoints.

*Ergonomic assessment of "fit" between users and product.
"JACK" software will also be used for virtual workstation design in the virtual workshop.

CONCLUSIONS

The paper has descried the possible application of Virtual Reality as an IT tool for educational purpose for engineering in the developing and least developing countries (LDC) of the globe, virtual reality has the ability to significally change in engineering education in many different areas including design, prototyping, design for maintenance and assembly, factory, factory planning, networking, chemical process design, etc in Bangladesh in future. In third world countries like Bangladesh research should be done on Virtual Reality as an educational tool, in order to determine which aspects of Virtual Reality provide the most effective educational benefits, and to learn the strength and weakness of this new technology in the educational setting to build a knowledge base of virtual reality techniques, tools, and expertise, which can then be applied to other problems at a later date. The paper also highlighted the on going research at IPE dept., Shahjalal University of Science and Technology, Sylhet. Virtual Reality environments could provide safe, economical, and quality hands–on training in the New Millennium for engineering students.

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