Virtual Reality Laboratories: An Ideal Solution to the Problems Facing Laboratory Setup and Management

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Abstract—***Virtual reality is an artificial environment created with computer hardware and software and presented to the user in such a way that it appears and feels like a real environment. This technology has been applied in all walks of life especially in education where it is used to simulate learning environments. So many universities and military establishments had adopted this technology and this had improved the learning capability of users. This paper presented lack of laboratory experience as the major problem associated with learning in science and engineering in Nigeria, and the way to overcome the problem through the use of virtual reality technology to simulate virtual reality laboratories.***

***Index Terms— Virtual Reality, Simulation, Laboratory, Second-life*.**

I. Introduction

Imagine you are inside a car driving without actually being inside that car; you as a pilot is undergoing training, flying, landing and crashing a plane without actually being inside that plane; you as a computer engineer, diagnoses faults and assembles computer systems without actually working with the real physical components. Imagine yourself as a surgeon, walks into an operating theatre, cut open the heart of a patient to change a defective valve. The scenarios described have been made possible through a technology known as virtual reality (VR). There were no real plane, real computer systems, real car and real patient. Everything was a computer simulation [1]. VR is an emerging technology on the horizon that will virtually place anyone in any experience desired [2]. It has had a wide acceptance in all walks of life.

Visualization and conduct of laboratory experiments are the most effective ways to simplify and clarify the comprehension of complex theory. Learning in engineering and science is a combination of understanding, conceptualization and practical experience. Therefore, learning in these fields today has been hampered by the absence or inadequacy of equipped laboratories, which no doubt have pitfalls such as constraints of time schedule, supervision, materials and cost. One way to overcome these difficulties is to use simulation programs to create learning environments such as VR laboratories. Computer-based virtual learning environments (VLEs) such as VR laboratories have opened new realms in the teaching, learning, and practice of medicine, physical sciences and engineering among others. VLEs provide students with the opportunity to achieve learning goals, without some of the mentioned constraints above. VLE-based applications have thus emerged in mainstream education in schools and universities as successful tools to supplement traditional teaching methods. These learning environments have been discovered to have greater pedagogical effectiveness on learners. Virtual learning environments provide three-dimensional (3D) insights into the structures and functions of any system desired. Students can thereby learn the principles of such system in a fast, effective and pleasurable way by interacting with and navigating through the environment created for such system [3].

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II. The Technology: Virtual Reality

VR is defined as a highly interactive, computer-based multimedia environment in which the user becomes the participant in a computer-generated world [4]. It is the simulation of a real or imagined environment that can be experienced visually in the three dimensions of width, height, and depth and that may additionally provide an interactive experience visually in full real-time motion with sound and possibly with tactile and other forms of feedback [5]. VR is a way for humans to visualize, manipulate and interact with computers and extremely complex data [6]. It is an artificial environment created with computer hardware and software and presented to the user in such a way that it appears and feels like a real environment [7]. VR is a computer-synthesized, three-dimensional environment in which a plurality of human participants, appropriately interfaced, may engage and manipulate simulated physical elements in the environment and, in some forms, may engage and interact with representations of other humans, past, present or fictional, or with invented creatures [8]. It is a computer-based technology for simulating visual auditory and other sensory aspects of complex environments [9]. VR incorporates 3D technologies that give a real-life illusion. VR creates a simulation of real-life situation [10].

A key feature of VR is real-time interactivity where the computer is able to detect user inputs and instantaneously modify the virtual world in accordance with user interactions. VR environments often consist of technological hardware including computers, head-mounted displays (HMDs), eye phones, and motion-sensing data gloves. VR technology has

offered strong benefits in science education not only by facilitating constructivist learning activities but also by supporting different types of learners such as those who are visually oriented and disabled [11].

In recent times, VR technology has been hyped. It is steadily finding its way in all areas of human endeavors most especially in education. One application and use of VR in education is in the development of Second Life. Second Life is a Web-based multi-user 3D virtual world developed by Linden Lab, a San Francisco-based company [12]. Second Life is one of the most popular virtual reality tools, attracting educators from all over the world by offering a variety of opportunities for interaction, sense of community, and users' self-building capabilities. Recent statistics showed that there are over 100 educational institutes (Harvard University taking the lead) that had established their virtual campus in Second Life and are actively working in the virtual world [13].

There are a lot of success stories as regards the application and use of simulated environment using VR technology. VR has extremely wide applications across a whole range of disciplines. It has reached a sufficient level of maturity, which has led to its application in education, training, and research in higher education. Vicher (Virtual Chemical Reactors) was developed at the University of Michigan in the department of Chemical Engineering [14]-[15] to teach students catalyst decay, non-isothermal effects in kinetics, reactor design and chemical plant safety since they believe that humans retain up to 90% of what they learn through active participation [11]. At the Kongju National University in Korea, a computer-based virtual reality simulation that helps students to learn physics concepts was developed. This virtual laboratory has helped students' gain laboratory experience and thus improved their performance [4]. In training and simulation, battlefield simulations have been developed using real data from Desert Storm [16]. The US Navy uses flight simulators to help train pilots for general navigation as well as special assignments.

III. VR Development Tools and Resources

There are many VR development tools and resources. Some of these tools and resources are free (open source to use), some are proprietary (closed source) [27]. VR related development is in progress regarding the availability, usability and capability of customization for existing development tools and resources. VR development tools and resources are quite numerous; some examples are presented:

A. Virtual Heroes Inc. (VHI)

This is an "Advanced Learning Technology Company" that creates collaborative interactive learning solutions for Federal Systems, Healthcare and Corporate Training markets [18].

VHI applications facilitate highly interactive, self-paced learning and instructor-led, distributed team training on its Advanced Learning Technology (ALT) platform. Major components of this platform include the Unreal® Engine 3 by Epic Games, and Dynamic Virtual Human Technology (DVHT).

ALT leverages simulation learning and digital game-based learning paradigms to accelerate learning, increase proficiency and reduce costs. DVHT combines best-in-class electronic computer game technology with a digital human physiology engine, digital pharmacokinetic drug models, accurate biomechanical parameters and artificial intelligence subroutines for the most realistic virtual humans available anywhere.

B. On-Line Interactive Virtual Environment (OLIVE)

This is a product of Forterra Systems Inc. Forterra Systems Inc. builds distributed virtual world technology and turnkey applications for defense, homeland security, medical, corporate training, and entertainment industries [19]. Using the On-Line Interactive Virtual Environment (OLIVE) technology platform, customers can rapidly generate realistic three-dimensional virtual environments that easily scale from single user applications to large scale simulated environments supporting many thousands of concurrent users. Forterra's technology and services enable organizations to train, plan, rehearse, and collaborate in ways previously considered impossible or impractical.

OLIVE combines multimedia, scalable computing and network enabled connectivity to provide a complete IT-ready platform for developing and supporting truly collaborative, multiplayer interactive virtual environments. It is a 3D client-server virtual world platform using PC clients connected to a central server via a network. The architecture scales from a Windows based development environment to large scale Linux clusters. This architecture supports many thousands of concurrent, geographically distributed users [21].

C. Icarus Studios Inc.

The company offers tools and products for creating massively multi-player online (MMO) environments, virtual worlds, and serious games for major entertainment, corporate, and government clients [17]. Icarus provides next generation technology, tools and production services enabling publishers and marketers to develop immersive environments to create new revenue streams and branding opportunities [22]. Icarus Studios products include compatibility with industry standard tools such as 3D Max, Collada, and other 3D applications with simple editors.

D. OpenSimulator (OpenSim)

OpenSimulator is a 3D application server. It can be used to create a virtual environment (world) which can be accessed through a variety of clients, on multiple protocols [17]. OpenSimulator allows you to develop your environment using technologies you feel work best. OpenSimulator has numerous advantages which among other things are:

1) It is released under BSD license, making it both open source, and commercially friendly to embed in products.
2) It has many tools for developers to build various applications (chat application, buildings, and avatars among others).
3) Open simulator can be extended via modules to build completely custom configuration.
4) It is a world building tools for creating content real time in the environment.

5) Supports many programming languages for application development such as Linden Scripting Language / OpenSimulator Scripting Language (LSL/OSSL), C#, and/or Jscript and VB.NET
6) It incorporates rich and handy documentations and tutorials.

E. Croquet

Croquet is an open source 3D graphical platform that is used by experienced software developers to create and deploy deeply collaborative multi-user online virtual world applications on and across multiple operating systems and devices [23].

Croquet is a next generation virtual operating system (OS) written in Squeak. Squeak is a modern variant of Smalltalk. Squeak runs mathematically identical on all machines. Croquet system features a peer-based messaging protocol that dramatically reduces the need for server infrastructures to support virtual world deployment and makes it easy for software developers to create deeply collaborative applications. Croquet provides rich tutorials, resources and videos as educational materials for developers.

F. Ogoglio

Ogoglio is an open source 3D graphical platform like Croquet. The main goal of the Ogoglio is to build an online urban style space for creative collaboration. Ogoglio platform is built from the languages and protocols of the web. Therefore, it's scripting language is javascript; its's main data transfer protocol is hypertext transfer protocol (HTTP), it's 2D layout is hypertext markup language (HTML) and cascading style sheet (CSS), and it has lightwave object geometry format for its 3D [24]. Ogoglio is very different from the other virtual reality world development platforms because it uses Windows, Linux, Solaris operating system platforms and runs on web browsers such as Internet Explorer, Firefox, and Safari.

G. Project DarkStar

This is a Java server side platform meant to accommodate massive multi online (MMO) users' environments.

H. WorldForge

This is an open source MMO project. It is a simple yet powerful tool for building Virtual worlds.

I. Blink 3D Builder

Blink 3D Builder is a proprietary authoring tool for creating immersive 3D environments. The 3D environments can be viewed using the a Blink 3D Viewer on the Web or locally.

J. QuickDraw 3D (QD3D)

QuickDraw 3D is a 3D graphics API developed by Apple Inc. starting in 1995, originally for their Macintosh computers, but delivered as a cross-platform system. QD3D provides a high-level API with a rich set of 3D primitives that is generally much more full-featured and easier to develop than low-level APIs such as OpenGL or Direct3D.

K. Autodesk 3d Max (3D Studio MAX)

Autodesk 3d Max formerly 3D Studio MAX is a modeling, animation and rendering package developed by Autodesk Media and entertainment. 3d Max is the third most widely-used off the shelf 3D animation program by content creation professionals. It has strong modeling capabilities, a flexible plugin architecture and a long heritage on the Microsoft Windows platform. It is mostly used by video game developers, television commercial studios and architectural visualization studios. It is also used for movie effects and movie pre-visualization.

IV. Problems Facing Laboratory Management As It Affects Learning

Learning, most especially distance learning, has been popularized in recent years because of the fast development of computer systems and the spreading of Internet connectivity. One of the major restrictions for learning in science and engineering education in Nigeria is the absence of equipped laboratories. Where laboratory is available, there is always the problem of obsolete and antiquated materials, which are seldom available for use. There is also the problem of laboratory attendants (experts), which even if available cannot be used to full capacity if the laboratory is to be run for 24 hours of the day and 7 days of the week and the cost implications of procuring and maintaining these laboratories and laboratory equipments/materials among others. There is also the problem of faulty equipments/materials that often times leads to electric shock, which in extreme cases leads to electrocution. Extending to physics/chemical laboratories, experimenting with radioactive substances has serious health implications. One way to overcome these difficulties is to use simulation programs instead of brick and wall physical hands-on experiments. However, most simulation programs used to demonstrate physical experiments are displayed in 2D and, thus, lack realism. A virtual reality simulation program is one solution for realistic hands-on experimentation.

V. The Need, Development And Use Of Virtual Reality Laboratory: The Benefits

One way to overcome the problems is the adoption and deploying of VR laboratories. The VR laboratories will serve as application for education, learning and training any area of human endeavor. The development and use of VR laboratories will increase student engagement, add realism to instruction, promote mastery and understanding of basic principles, augment laboratory experience, and encourage inferential and exploratory learning. Thus, VR offers to bring exciting possibilities, which were once considered science fiction. Since VR is a good medium for illustrating concepts that have been covered elsewhere, and for presenting three-dimensional objects and relationships, therefore the action and immersion of VR will improve long-term retention of material. Reference [11] has shown that we only remember 10% of what we read, and 20% of what we hear, but that we retain up to 90% of what we learn through active participation. Many organizations are exploring virtual reality to create numerous simulated environments.

The benefits of virtual reality tools in computer engineering laboratory will among other things:

1) Give the capability to really have a laboratory experience with the students.
2) Provide motivation for learning.
3) Can illustrate some features, processes etc. more accurately than by other means.
4) Allows extreme close-up examination of an object and allows observation from a great distance.
5) Allows the disabled to participate in an experiment or learning environment when they could not have been possible.
6) Allows the learner to proceed through an experience at his own pace.
7) Allows the learner to proceed through the experience during a broad time period not fixed by a regular laboratory schedule.
8) Provides experience with new technologies through actual use.
9) Requires interaction. Encourages active participation rather than passivity.
10) It is cost effective as in the case of the electronics laboratory; students will deface and damage the virtual printed circuit board (VPCB) without actually doing any harm to it.
11) There will be no risk of electrocution/electric shock even if there are mistakes made by a student.
12) Physical phenomena that are neither easy to perceive nor to measure in usual experiments can be presented in a virtual world and can be viewed in many different perspectives in a VR laboratory.
13) In addition, dangerous, high cost, and complicated experiments can be realized in a VR system.

VI. Applications And Advancements in Virtual Reality Technology

Many virtual reality applications have been developed for manufacturing, especially in the areas of training, simulation, and rapid prototyping, due to its power of transporting the customers to a virtual environment and convincing them of their presence in it [25].

The Boeing developed the Virtual Space eXperiment (VSX). The VSX is a demonstration of how virtual environment systems can be applied to the design of aircraft and other complex systems involving human interactions [26]. It is a 3D virtual model of the interior and exterior of a tilt-rotor aircraft in virtual space that allows persons to interact with various items such as maintenance hatch, cargo ramp.

A virtual-reality-based point-and-direct (VR-PAD) system was developed to improve the flexibility in passive robot inspection [27]. An operator in a remote control room monitors the real working environment through live video views displayed on the screen and uses the virtual gripper to indicate desirable picking and placing locations. The robot in the inspection system completes material handling as specified so that the system can achieve flaw identification. The CERN, European Laboratory for Particle Physics, performed the pilot project that evaluated and promoted the use of virtual environment technology which helped in designing, building and maintaining the Large Hedron Collider (LHC) premises and equipment [28]. The project consists of several applications, such as network design and integration, territory impact study, and assembly planning and control to respond to the needs of LHC engineers.

In education VR technology has found a place. At the University of Michigan, Ann Arbor [29] – [30], two research fellows developed Vicher (Virtual Chemical Reactors) in the department of Chemical Engineering to teach students catalyst decay, non-isothermal effects in kinetics and reactor design and chemical plant safety since they believe that humans retain up to 90% of what they learn through active participation [11]. The most exciting possibilities in terms of education and VR are found as it is implemented in the education of the disabled.

The VR technology promises to shorten a product development cycle greatly by skipping the need for physical mockups [31]. The Ford's Alpha simultaneous engineering team developed the virtual reality system for evaluating process installation feasibility in automotive assembly.

In Japan, the customers bring the architectural layout of their home kitchen to the Matsushita store and plug it into the computer system to generate its virtual copy [32]. They can install appliances and cabinets, and change colors and sizes to see what their complete kitchen will look like without ever installing a single item in the actual location.

Similarly, Mike Rosen and Associates has been using an interactive and immersive virtual reality technology to assist its building industry clients in the design, visualization, marketing, and sales [33]. The applications let the customers become actively involved in the visualization process, such as making changes of colors, textures, materials, lighting, and furniture on the fly.

Researchers at NASA Johnson Space Center in Texas have developed an impressive virtual learning environment for high school students--a virtual physics laboratory which enables students to explore such concepts as gravity, friction, and drag in an interactive, virtual environment. Students have several balls and a pendulum with which to work. They also have several investigative tools, such as a distance measuring device and a digital stopwatch. In addition, the computer provides several interesting capabilities such as the ability to view dynamic events in slow motion or to show trails on objects to better show their movements [34].

VII. Conclusion

A lot of advancements have been made using VR. VR is a technology that has cut across all facets of human endeavours-manufacturing/business, exploration, defense, leisure activities, and medicine among others. In education VR promises to be rewarding. At the University of Michigan, Ann Arbor, Vicher (Virtual Chemical Reactors) was developed in the department of Chemical Engineering to teach students catalyst decay, non-isothermal effects in kinetics and reactor design and chemical plant safety since it is believed that humans retain up to 90% of what they learn through active participation. At NASA Johnson Space Center in Texas a virtual physics laboratory was developed

which enables students to explore such concepts as gravity, friction, and drag in an interactive, virtual environment. Students have several balls and a pendulum with which to work. Since, one of the major restrictions for learning in science and engineering education is the absence of equipped laboratories, VR laboratories will overcome this problem and other problems associated with laboratory management most especially in developing countries.

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