ISSN: 2688-8653

Virtual Reality Lab, The Future Direction of Teaching Labs?

Ran Zhao*

Sichuan University of Media and Communications,College of Art Design and Animation, Chengdu, Sichuan, 611745, China

Abstract

The key technology of using virtual reality technology to establish virtual laboratory is introduced, and the importance of the development of virtual laboratory is expounded. This paper firstly introduces and analyzes the current situation and development trend of virtual laboratory, and introduces related theories and frameworks. Then it discusses the establishment of the virtual laboratory model, the virtual entity operation technology and the technology used in the process control virtual laboratory system. Finally, this paper discusses the advantages of virtual reality-based laboratories over traditional laboratories, including improving teaching efficiency, completing impossible experiments, improving classroom interest, and enriching classroom teaching forms.

Keywords

Virtual Reality; Virtual Reality Lab; Teaching Lab.

1. Introduction

Virtual Reality (VR), which emerged in the late 1980s, is the latest technology in the field of computing. It creates a three-dimensional graphical world for users that reflects changes in physical objects in real time and interacts with them in a simulated way, allowing participants to gain direct involvement in the perceptual behavior of seeing, hearing, touching, and feeling. and explore the role and changes of virtual objects in the environment in which they are placed. The development of virtual reality technology is driven by science and technology (Jimenez et al., 2021). In essence, virtual reality is an advanced computer user interface that provides users with a variety of intuitive and natural real-time perceptual interactions such as visual, auditory, and haptic, maximizing user convenience and thus reducing the burden on users and increasing their experience of using the system (Howard, 2019). Depending on the object of application, the role of virtual reality can take different forms, such as visualizing and manipulating a concept or notion, achieving realistic live effects, and implementing inexpensive simulations of any complex environment for training purposes (Pletz, 2021).

The distance between the experiment and the experimenter determines its main difference from a practical laboratory. Real experimental data are obtained by controlling shared and geographically separated equipment (Hu Au & Lee, 2017). The educational effect between the practical laboratory and the remote version is conditional and limited. However, the control of a remote laboratory is like the control of a robot in remote manufacturing. Virtual labs can provide a way to share skills and resources, thus improving the educational experience. They also have additional advantages such as availability, observability, accessibility, and safety. An important issue is to assess whether virtual and remote labs can provide learning outcomes similar to those of hands-on labs. The different perspectives on the educational goals of hands-on and virtual labs have not yet converged.

2. Literature Review

2.1. Virtual Laboratory

A virtual laboratory is defined as a class of experimental systems suitable for virtual experiments generated using virtual reality technology, including the corresponding laboratory environment, relevant experimental instruments and equipment, experimental objects, and experimental information resources. The virtual laboratory can be a real realization of the real laboratory, but also the virtual concept of the laboratory (Salzman et al., 1999). In the virtual laboratory, the experimenter has a sense of realism, as if he is close to the scene in the real laboratory operation. The application of computers to establish virtual instruments capable of objectively reflecting the laws of the real world for virtual experiments, in response to the practical problems that exist, we have studied the use of computers to simulate experiments and to realize the simulation through virtual reality technology in the main experimental processes of the process control course, the process control network virtual laboratory was established.

The visual nature of the virtual laboratory makes it ideal for teaching applications. The combination of multimedia computer technology and instrumentation technology forms the basis for the implementation of the virtual laboratory, where students can have their own laboratory on the computer screen through a scenario-based graphical interface (Bogusevschi et al., 2020). The combination of virtual instrumentation technology and cognitive simulation methods also gives the virtual laboratory an intelligent character, allowing students to observe experimental phenomena in an immersive manner via the Internet and observe each experimental instrument in detail, without the constraints of time and space. Some experimental apparatuses are mostly expensive and the experimental process is dangerous, which certainly limits the number of users (Zhao & Shen, 2022). Microcomputers are inexpensive and easy to operate, making it possible to apply virtual laboratories in the fields of teaching, science education and technical research.

2.2. Construction and Use of Virtual Laboratories

Laboratories were originally designed for scientists to conduct research and discoveries. At that time, little effort was made to allow students to learn by doing and participating in laboratory experiments. They were taught through lectures and textbooks and, on rare occasions, equipment was demonstrated in the classroom (Jie Huang, 2019). Researchers and students have different priorities when using the labs. Researchers have three main objectives: a) to collect and analyses data to design and develop products; b) to determine whether a given design performs as envisaged; and c) to generate new knowledge. For students, the main objective is to learn from the knowledge that has been generated. Each laboratory format has its own strengths and weaknesses when it comes to teaching and learning(Abd Majid & Mohd Shamsudin, 2019). Handson labs promote interaction and collaboration; they also allow students to learn through iterative experiments. However, students need supervision and have limited time to conduct experiments. The main advantage of a virtual lab is the safety it provides when managing hazardous equipment and reagents. It also provides flexibility as students can conduct experiments at any time. The main disadvantage is that teaching is not feasible and there is no obvious equipment (Psotka, 1995).

In recent years, a number of virtual laboratory studies have emerged accordingly; virtual language laboratories, virtual soil crop systems laboratories, online virtual laboratories for engineering testing, virtual chemistry laboratories, virtual physics laboratories, virtual biology laboratories, virtual reality laboratories, etc. Virtual laboratories are characterized by the ability to operate a variety of experimental apparatus to complete various analytical tasks in an autonomous and flexible manner, and to evaluate the experimenter's level of operation and

ISSN: 2688-8653

practical skills. Many universities have also conducted research on virtual laboratories, and laboratories around the world are connected through networks to become online virtual large-scale laboratories. Beijing University of Aeronautics and Astronautics has established a virtual immunohistochemistry laboratory in collaboration with the Pathology Quality Control Centre of Zhejiang Province.

3. Design Platform for Virtual Laboratories

3.1. Virtual Laboratory Structure

The creation of a virtual laboratory is extremely complex. It must be object-oriented and real-time, with inherent flexibility and portability, which places high demands on the software development environment. Superscape's VRT, VRT allows for a high degree of network processing and interactivity. Using a PC as the hardware platform, the system uses VRT, a desktop virtual reality environment programming platform developed by Superscape UK based on Direct3D, whose most important feature is the introduction of object-oriented technology and the integration of currently popular visualization techniques. interface. It is also highly scalable, allowing for a high degree of interactivity and network handling (Anthes et al., 2016). VRT creates a truly interactive 3D world where the experimenter can immerse themselves in the experimental device, observe changes and results and navigate locally or on the Internet via the viewer. VRT is advanced professional level development software for the PC, running on Windows 95/98 and Windows NT platforms, with over 700 interactive toolboxes, over 1000 3D virtual models and over 800 SCL command sets. 3D models can be imported and exported in DXF format, and image files such as PCX, BMP, JPG and TGA, as well as WAV and SMP sound files are supported. The VRT software development team includes seven virtual reality editors to create complex 3D interactive simulation scenarios without programming. Many control functions (e.g. logic operations, dynamic exchange with external data, etc.) can be executed using the SCL high-level language, which can significantly reduce the development time of virtual reality applications.

3.2. Tree Hierarchy of the Scenario Database

A complete virtual reality system can be broken down into visual, auditory, and haptic subsystems. Professor Mark Green gives a concise model state of a virtual reality application system, as shown in Figure 1. In this case, computation includes all non-graphical computations in the application; geometric modelling includes high-level graphical representations of data in computation, or visualization of scientific computations; and observation refers to the user viewing the application data, i.e. the content graphically represented with a sense of reality. Active agents are those that simulate the user's interaction with objects in the system in the same way.

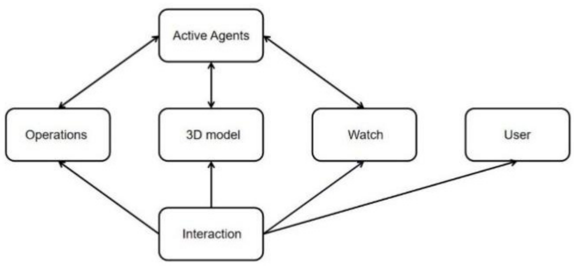

Figure 1. Virtual Reality System Model

The scene model obtained after 3D modelling is managed and manipulated as a scene database. The scene database reflects all the details of the real environment corresponding to the virtual

ISSN: 2688-8653

scene and is a realistic 3D environment. It primarily describes all visible objects in the scene and their relative positions, and is used to generate realistic images and provide realistic visual feedback. Geometric modelling of objects is a prerequisite for generating high quality landscape images; it is an abstract model for describing the intrinsic geometric properties of objects. A rational model organization is necessary for the experimenter to interact with the virtual apparatus and therefore a tree hierarchy of entity models in the virtual scene needs to be determined based on the geometric spatial location of the individual entities in the virtual laboratory and the structural relationships between the models. This hierarchy allows us to decompose the model objects using a top-down approach and reconstruct them using a bottom-up construction method, dividing all objects into the most efficient tree structure using two parents, children, and brothers. This tree structure not only provides a simple and natural way of dividing complex objects, but is also very beneficial for model modification. The hierarchical division of the scene facilitates the organization and management of the physical model, while the hierarchical division within the physical model allows the complex model to be decomposed into a number of basic units from the top down, clarifying the model building objectives and greatly reducing the modelling effort. At the same time, the structure of the scene model can be adjusted and optimized to improve the quality of the scene system when scheduling the scene image output (Wojciechowski & Cellary, 2013).

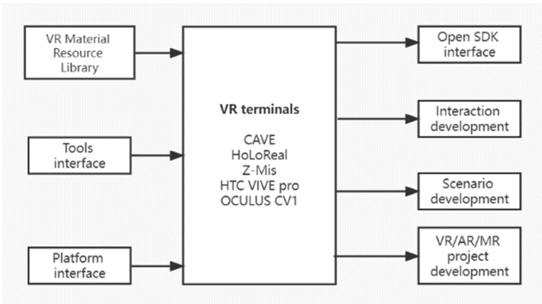

Figure 2. Components of the VRT

3.3. Three-dimensional Models

3.3.1. Production

The three main 3D modelling methods currently in use are 3D software modelling, instrumental modelling, and video-based modelling. Commonly used 3D modelling software includes 3Dmax, Maya and AutoCAD, which generally use basic and extended geometry to construct complex geometry such as translation, rotation, stretching or Boolean operations. The creation of 3D models through computer software applications includes the commonly used Geometric Modelling > Motion Modelling, Physical Modelling > Object Behavior and Model Segmentation (Gonçalves & Badia, 2018). Geometric modelling is the main modelling method used in this study and is mainly used for the construction of virtual scenes. A 3D scanner is the main tool for 3D modelling of real objects. It is characterized by its ability to quickly convert actual stereo color information into a digital signal that is processed by a computer to load the modelling data. The advantage of a 3D scanner is that it can scan in three dimensions, moving away from the traditional two-dimensional scanning of flatbed scanners, cameras etc. 3D scanners are classified as contact or non-contact, with contact scanners working physically to touch the object, analyses its surface and calculate its depth. However, it is inevitable that the object to be measured will be damaged (Zhao et al., 2020). It is for this reason that contact scanners are not suitable for reconstructing high value objects. In addition, today's fastest CMMs are already capable of making hundreds of measurements per second, while laser scanners operate at a rate of 10,000 to 5 million measurements per second, thus significantly reducing scanning times. Non-contact active scanning works by using energy projection and reflection for three-

ISSN: 2688-8653

dimensional calculations to produce a three-dimensional model of the object, with the main sources of energy being visible light and rays. One of the most active research areas in computer graphics is image-based modelling and rendering (IBMR), a technique that turns the perception of modelling on its head. Unlike traditional modelling techniques, IBMR allows objects to be modelled faster and more easily, maintaining their original realism, and increasing efficiency (Rajesh Desai et al., 2014).

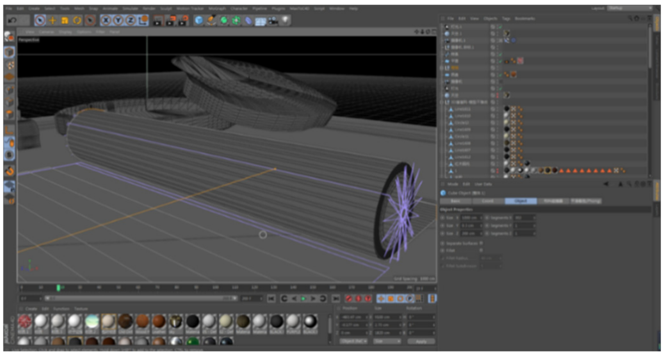

Figure 3. Modeling with 3DMAX

3.3.2. Location Tracking Technology

Position tracking actually refers to the real-time detection of the specific position of the observed object in three-dimensional space, similar to GPS navigation. Currently, the mainstream technologies are divided into five categories: optical, inertial, electromagnetic, mechanical and ultra-wideband technologies (Marks & Thomas, 2021). In general, optics is divided into several schools of thought, one of the categories based on the number of cameras and the number of marker points are divided into single camera single marker point (PSMOVE), single camera multiple marker points, such as PSVR, Oculus, HTC VIVE, SLAM, Ximmerse and other multi-camera single marker point, depth VR. Optitrack and several other programs, relatively single marker positioning capture is relatively fuzzy and can only show the 3Dof position information of the detected object in space, while the multi-marker positioning method is relatively accurate and can feedback the 6Dof information of the object detected in space. Position tracking is the core of virtual reality devices and the most complex part. Accuracy and precision are common metrics for location tracking, which are measured by repeatedly measuring the same point in the play area and then comparing the similarity. The location tracking solutions currently in use have their advantages and disadvantages, but the HTC VTVE device, for example, uses Lighting House tracking and positioning technology, which is a more mature VR optical tracking solution(Rajesh Desai et al., 2014).

3.3.3. Global Light Technology

Global illumination is a term specific to 3D software and is a model that represents how light works when it is reflected from one surface to another. Light has both reflective and refractive properties. In real nature, the light we typically see from the sun to the ground undergoes many reflections and refractions, meaning there are no blank spots on the ground where we see the light. However, the radiant energy transfer of light is not very obvious (Kopylov & Dmitriev, 2000). Before global illumination is enabled, the 3D software only calculates the dark and light surfaces, but when enabled, it calculates the reflection and refraction of light. Global illumination is a combination of direct and indirect lighting effects that perfectly renders real-world natural light by controlling the optics of reflection and diffuse reflection. Therefore, in order to obtain the closest realism, this study requires the use of global illumination techniques, which can be implemented in a variety of ways, including radiant luminance, ray tracing, ambient occlusion, photon mapping, and light detection. Although the advantages are great, there are some disadvantages. Global illumination is computationally intensive, requires high

ISSN: 2688-8653

hardware requirements, and takes a long time to render images using global illumination, so we need to use this technique in conjunction with real applications, combining static baking and dynamic global illumination to improve rendering efficiency and achieve realistic scene reproduction without consuming too many resources (Wang et al., 2021).

4. Discussion

With the maturity of VR technology, people began to realize the application value of virtual simulation laboratory in the field of education. Compared with the inevitable limitations of the traditional teaching mode, the virtual simulation laboratory breaks through the traditional education informatization mode, has many advantages such as high utilization rate and easy maintenance, can achieve better teaching effects, and highlights the advantages of experimental teaching. advantage and efficiency. Improve the teaching effect: The realistic and three-dimensional form of expression can vividly show the abstract experimental process, so that students can see it very much like the real thing. At the same time, we can also see some things that cannot be seen in reality through this virtual simulation, and some things that humans cannot see or can only see with the help of instruments, can also be seen through this technology. Therefore, if the student can see this intuitive image, it is easier for him to accept it. Teachers can give full play to the advantages of virtual component resources and improve teaching effects according to actual teaching needs. At the same time, it can complete impossible experiments and assist teachers to demonstrate classroom experiments: such as complex experiments, dangerous experiments, extremely destructive experiments, experiments with too long reaction periods, experiments that cannot control the reaction process, traditional laboratories Experiments that cannot be completed can be displayed safely and intuitively. It can enhance the fun of the classroom, with the help of multimedia (audio, video, image) technology, virtual simulation technology, sensing technology, input and output technology, to build a highly virtual reality simulation experiment teaching environment, so that learners can experience the immersive experience To a large extent, it can realize interactive experimental teaching, stimulate students' interest in independent experiments and the impulse to solve the mystery of the subject to the greatest extent, which is conducive to cultivating students' constructive thinking and has a unique practical role in experimental teaching. It can provide a wealth of classroom teaching forms. The emergence of virtual simulation teaching will no longer be a situation where the experiment cannot be completed and the teacher can only explain with one mouth. In traditional experiments and traditional teaching, teachers often speak from above and students watch from below. For students, many students know that after the teacher finishes the experiment, the result will come out. However, virtual simulations are different. It allows students to explore on their own. In this way, you can see whether the result is the case, break through the dependence of experimental teaching on objective conditions, meet the actual needs of classroom teaching, and gradually become a powerful experimental production tool for teachers.

5. Conclusion

The network and visualization characteristics of virtual laboratory make it very suitable for distance learning. It can solve the problems of insufficient teaching funds and outdated teaching equipment. It facilitates dangerous and difficult research experiments in the laboratory. This makes the virtual laboratory very suitable for the application in distance education. The virtual laboratory is intuitive, flexible and convenient, which is conducive to cultivating students' innovative ability and creativity. Virtual reality is used to simulate the real world. Through the computer network, users can realize the remote operation of instruments or meters without being limited by time and space, thus saving money, convenience and flexibility, and providing

ISSN: 2688-8653

a good example for distance education At the same time, the following suggestions are put forward for the construction of the virtual laboratory. First, the system communication, network bandwidth limitation and network delay are the main obstacles of the virtual laboratory. It is necessary to establish various conditions that are suitable for multiple users, multiple communication bandwidths and software systems. The second is the desktop distributed experiment, where multiple users collaborate on multiple computers to complete an experiment at the same time. Finally, due to the hardware conditions, the experiment does not interact with the actual instrument. The interface allows the combination of software and hardware, giving users more experience and more possibilities.

References

[1] Abd Majid, F., & Mohd Shamsudin, N. (2019). Identifying factors affecting acceptance of virtual reality in classrooms based on Technology Acceptance Model (TAM). Asian Journal of University Education, 15(2), 52–60. https://doi.org/10.24191/ajue.v15i2.7556.

[2] Anthes, C., García-Hernández, R. J., Wiedemann, M., & Kranzlmüller, D. (2016). State of the art of virtual reality technology. IEEE Aerospace Conference Proceedings, 2016-June(March). https:// doi.org/ 10.1109/AERO.2016.7500674.

[3] Bogusevschi, D., Muntean, C. H., & Muntean, G.-M. (2020). Teaching and Learning Physics using 3D Virtual Learning Environment: A Case Study of Combined Virtual Reality and Virtual Laboratory in Secondary School. Journal of Computers in Mathematics & Science Teaching, 39(1), 5. https:// ezp. waldenulibrary.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=edo&AN =142858119&site=eds-live&scope=site.

[4] Gonçalves, A., & Badia, S. B. I. (2018). KAVE: Building kinect based CAVE automatic virtual environments, methods for surround-screen projection management, motion parallax and full-body interaction support. Proceedings of the ACM on Human-Computer Interaction, 2(EICS). https: // doi.org/10.1145/3229092.

[5] Howard, M. C. (2019). Virtual Reality Interventions for Personal Development: A Meta-Analysis of Hardware and Software. Human-Computer Interaction, 34(3), 205–239. https:// doi.org/ 10.1080/ 07370024.2018.1469408.

[6] Hu Au, E., & Lee, J. J. (2017). Virtual reality in education: a tool for learning in the experience age. International Journal of Innovation in Education, 4(4), 215. https:// doi.org/ 10.1504 /ijiie. 2017. 10012691.

[7] Jie Huang. (2019). Talking about the Advantages and Disadvantages of the Application of Virtual Reality Technology in Psychological Research. Advances in Psychology, 09(03), 552–557. https:// doi.org /10.12677/ap.2019.93069.

[8] Jimenez, I. A. C., García, L. C. C., Violante, M. G., Marcolin, F., & Vezzetti, E. (2021). Commonly used external tam variables in e-learning, agriculture and virtual reality applications. Future Internet, 13(1), 1–21. https://doi.org/10.3390/fi13010007.

[9] Kopylov, E. A., & Dmitriev, K. A. (2000). Light propagation visualization as a tool for 3D scene analysis in lighting design. Computers and Graphics (Pergamon), 24(1), 31–39. https:// doi.org/ 10.1016/ S0097-8493(99)00135-1.

[10] Marks, B., & Thomas, J. (2021). Adoption of virtual reality technology in higher education: An evaluation of five teaching semesters in a purpose-designed laboratory. Education and Information Technologies, 0123456789. https://doi.org/10.1007/s10639-021-10653-6.

[11] Pletz, C. (2021). Which Factors Promote and Inhibit the Technology Acceptance of Immersive Virtual Reality Technology in Teaching-Learning Contexts? Results of an Expert Survey. International Journal of Emerging Technologies in Learning, 16(13), 248–272. https:// doi.org/ 10. 3991 /ijet.v16i13.20521.

[12] Psotka, J. (1995). Immersive training systems: Virtual reality and education and training. Instructional Science, 23(5–6), 405–431. https://doi.org/10.1007/BF00896880.

ISSN: 2688-8653

[13] Rajesh Desai, P., Nikhil Desai, P., Deepak Ajmera, K., & Mehta, K. (2014). A Review Paper on Oculus Rift-A Virtual Reality Headset. International Journal of Engineering Trends and Technology, 13(4), 175–179. https://doi.org/10.14445/22315381/ijett-v13p237.

[14] Salzman, M. C., Dede, C., Loftin, R. B., & Chen, J. (1999). A model for understanding how virtual reality aids complex conceptual learning. Presence: Teleoperators and Virtual Environments, 8(3), 293–316. https://doi.org/10.1162/105474699566242.

[15] Wang, Z., Philion, J., Fidler, S., & Kautz, J. (2021). Learning Indoor Inverse Rendering with 3D Spatially-Varying Lighting. Proceedings of the IEEE International Conference on Computer Vision, 12518–12527. https://doi.org/10.1109/ICCV48922.2021.01231.

[16] Wojciechowski, R., & Cellary, W. (2013). Evaluation of learners' attitude toward learning in ARIES augmented reality environments. Computers and Education, 68, 570–585. https:// doi.org/ 10.1016 /j.compedu.2013.02.014.

[17] Zhao, R., Geng, J., & Shen, Y. (2020). Digital media vision innovation based on FPGA and Convolutional Neural Network. Microprocessors and Microsystems, 103465. https:// doi.org/ 10.1016/ j.micpro.2020.103465.

[18] Zhao, R., & Shen, Y. (2022). Learning and Teaching Cameras Using Virtual Reality Games -- A Case Study of the Combination of Virtual Reality and Virtual Lab in Universities. 4(4), 295–303.