

Construction of Chemical Virtual Laboratory Based on Computer Simulation Technology

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With the expansion of students' scale and the considerations for students' safety are increasing, the schools' demand for virtual chemistry laboratories in chemistry teaching is increasing. Based on this background, combining with VIRTTOOLS platform, PHOTOSHOP, 3D MAX and other software, this paper uses the computer simulation technology to develop a chemical virtual laboratory software. The virtual laboratory takes the experimental operation, experimental process explanation and monitoring, and experimental result feedback as the core functions, and it takes virtual roaming, external hardware and multimedia as assisted functions. The test results for the virtual laboratory show that the virtual laboratory has superior performance in experimental scene perception, experimental interaction, ease of use, and versatility, and is suitable for large-scale promotion. In addition, during the construction process of the virtual laboratory, this paper draws the following conclusions: selecting the scenario mode as the virtual laboratory construction mode can maximize the experimental scene perception and experimental interactivity; using software platform instead of a single software as main development technology can effectively improve the ease of use and the versatility of the virtual laboratory.

1. Introduction

Unlike common disciplines, chemistry cannot be separated from experiments. It can be argued that chemistry experiment teaching is a necessary way to cultivate students' operational ability and thinking ability. Only by experiments can students understand various abstract concepts in chemistry deeply, and lay a good foundation for chemistry learning (Gonçalves-Maia, 2015). At present, the chemistry education in high schools and universities has taken the experimental courses as essential curricula, and they assist theoretical teaching by introducing a large number of experimental equipment.

However, during this process, schools often encounter various problems, mainly including the following aspects: first, chemical experimental equipment is quite expensive, and not all schools have sufficient funds (Jovanović and Veinović, 2016); second, under the condition that the number of school personnel is increasing, experimental equipment often cannot meet the demand (Chu and Leung, 2003); last, in the course of chemical experiments, students often cause accidents due to improper operation, which may lead to damages to the experimental equipment, or even cause casualties (Herga et al., 2016).

The development of computer technology provides a feasible way to solve the above problems. In recent years, virtual reality (VR) technology, augmented reality (AR) technology, and simulation technology have been applied to teaching in various fields and have achieved good results (Xu, 2018; Meuzelaar, 1997; Herga, 2012).

Some European and American colleges and universities use VR technology and simulation technology to build physics labs so that students can directly manipulate physics experiments with virtual controllers in the classroom (Hoffmann, 2013). In this context, this paper introduces computer simulation technology into the teaching of chemistry experiments, by setting up a virtual environment laboratory, it discusses the application effects and scenarios of computer technology in chemistry teaching, so as to provide feasible solutions for various dilemmas in school chemistry experiment teaching in China.

2. Simulation technology and virtual laboratory

2.1 Simulation technology

Simulation refers to a technique that simulates real-world physical objects using computers and mathematical methods (KemalTurhan, 2006). For the chemistry field, specifically, chemical simulation can be considered as a process that uses computer technology to conduct online chemical experiments, it's a technology that replaces the real experimental environment by a simulated chemical experiment operating environment for the use of related personnel (Paulsson et al., 2008). Generally speaking, simulation technology does not refer to a specific, single technology, it includes a set of technical sequences including VR, AR, artificial intelligence (AI), and distributed processing.

2.2 Virtual laboratory

Virtual laboratory refers to the collection of systems built by hardware and software to replace the real experimental environment, it uses multimedia, simulation technology and other technologies, and is created on computers and other related equipment (Jaffee, 2003). Experimenters can achieve the same effect in a real environment by operating hardware and software systems as in a real laboratory.

At present, virtual laboratories can be divided into two large categories (Assaf et al., 2009): the first is the stand-alone virtual laboratory, which refers to a virtual laboratory that is used as much as possible on local instruments or on a single equipment, its scope of application is smaller, and the degree of openness is not sufficient; the second is online virtual laboratory, which means that the software underlying system of the virtual laboratory is stored in the cloud or in the server, users only need to update or download the software system before using the hardware, it has characteristics of easy-to-use, no location restrictions and high openness. Considering that chemical virtual laboratory has the characteristic of promotional, therefore, the virtual laboratory this paper refers to is the online virtual laboratory.

3. Overall design of virtual laboratory

Complete functionality is the users' basic requirement for virtual laboratory (Peetz et al., 2014). Therefore, the chemical virtual laboratory involved in this paper contains all the important chemical experimental scenarios in China's middle school, high school and university, and we can further add experimental modules according to the different needs of users. Specifically, each specific experimental function includes two parts: core function and assisted function. The core functions include parameter adjustment, experimental process explanation and monitoring, experimental result feedback, etc.; assisted functions include virtual roaming function, external hardware function, multimedia function, etc. In the following passages, this paper will introduce how to implement the above functions from three perspectives of construction mode, development tools and technical route.

3.1 Selection of construction mode

Currently, popular virtual laboratory construction modes include scenario jumping mode, process mode, playing/viewing mode, and scenario mode (Dosta et al., 2012). Scene mode is currently the most widely used mode, because it has the features of good interactivity, high integrity, realistic scenes, and participants can experience the whole experiment operating process personally. Therefore, this paper also chooses the scenario mode as the basic mode for the construction of virtual chemistry laboratory.

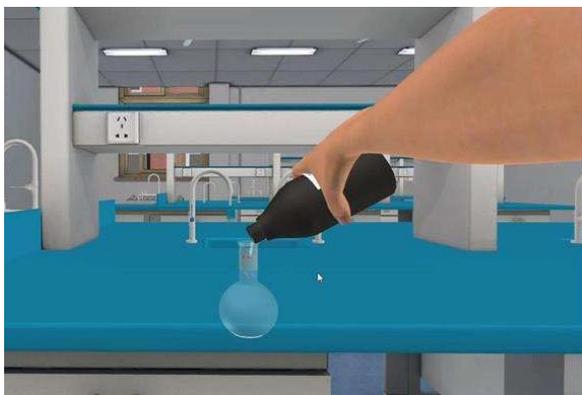


Figure 1: Presentation of scenario mode

3.2 Development tools

From a technical point of view, common computer simulation technologies include VRML technology, MATLAB technology, JAVA technology, and VIRTOOLS platform technology. By comparison, this paper found that, compared with the first three technologies, VIRTOOLS technology has advantages in terms of functionality, interactivity, ease of operation, picture aesthetics, etc., and can also be used with other assisted technologies (Mills, 1996).

Therefore, this paper plans to use the VIRTOOLS platform technology to develop the experimental environment together with PHOTOSHOP and 3DS MAX technologies.

3.3 Technical route

This paper selects to develop the chemical virtual laboratory based on the VIRTOOLS platform technology, thus the four main processes for development are determined, respectively are:

- (1) Model building;
- (2) Model importing;
- (3) Content development;
- (4) Playing and experiencing stage. The combination situation of major technologies and processes: first use VIRTOOLS technology to process the graphics material, then use VIRTOOLS technology to model the 3D scene, and then import the model into the VIRTOOLS platform, at last program to finish the final design and test.

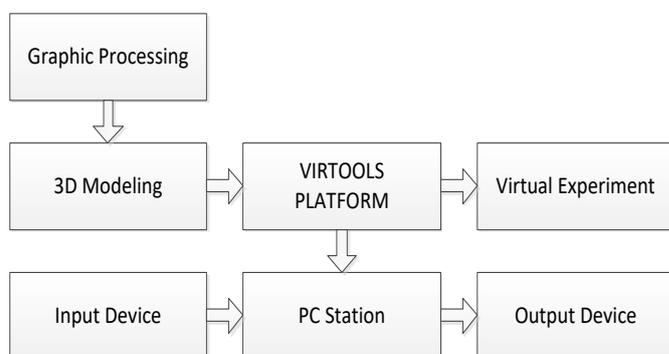


Figure 2: Virtual laboratory development technical route

4. Interaction design and implementation methods

Realizing human-computer interaction in a virtual environment is an important part of the virtual laboratory and is also a difficult point in design and development (Amin et al., 2016). This paper mainly uses 3D MAX technology to realize the demand for human-computer interaction in VIRTOOLS platform through mode design, task control, and action coordination.

4.1 Virtual laboratory scenario implementation

In the VIRTOOLS platform, we can use multi-scenario design modules to design specific laboratory scenarios and other virtual scenarios, so as to increase the virtual laboratory's authenticity. In addition, the multi-scenario design module of the VIRTOOLS platform has the function of instant calling, which can realize the free change of the object between 3D and 2D images and it reduces the design workload. In addition, the scenario design module can also observe the same three-dimensional scenario from different angles, which also makes the virtual experimental scenario have better authenticity. The interactive virtual scenarios designed using the VIRTOOLS platform are shown below.



Figure 3: Virtual scenario design effect

4.2 The realization of chemical experiment process

In the designing process of the virtual chemistry laboratory, the most complicated work is to design the experiment realization and interaction process for each chemical experiment. Due to limited space, this paper cannot present the implementation process of all experiments, so only the implementation process of the gas-liquid observation experiment is shown.

Gas-liquid observation is a unique phenomenon in the process of chemical distillation, so the simulation of this phenomenon can greatly enhance the authenticity of the experiment. This paper first calls the BB module in the VIRTTOOLS platform to imitate the particle form of gas particles in the air, perform 2D modeling first and then 3D modeling. In addition, the LIFESPAN, EMISSION, and SPEED parameters in the BB module are used to control the diffusion state of gas particles in the experimental process, if we zoom in the visual environment during the virtual process, we can also see the physical collision of gas ions. This paper shows the real effects of the gas-liquid observation experiment as follows.

Some of the code for experiment flow and time control is shown below.

```
{!G.ReallabPosition;
If (a.z=240 && Timemin<time<Timemax)
{Route(0,1,2); Timemin+=1;}
If(a.z=240 && Timemin>0)
{ Route(0,1,2);Timemin-=1;}
Flowtext="";
Flowtext+= Timemin*2;
Formatstring(Flowtext,4);
//bc.outputtoconsole(Timemin);
Tdout=true;}
```

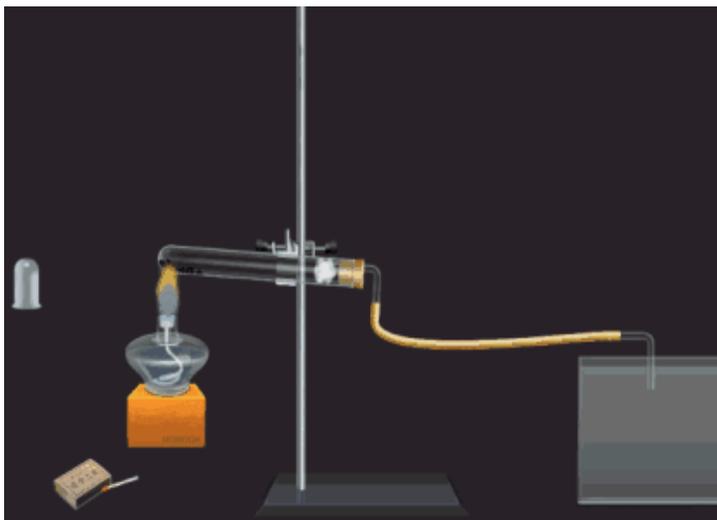


Figure 4: Experimental demonstration

4.3 Test and evaluation

The virtual laboratory designed in this paper is used in the form of software and should be tested for functional validity and completeness before use.

Besides testing on hardware devices inside the research team, software applications of the virtual laboratory have also been placed on an international domain name website for download and use by school researchers around the country. The virtual laboratory designed in this paper is very small after compression and only has 34MB. It can be easily uploaded to a web server for use by users other than local users. In addition, the virtual laboratory also includes interactive learning and online discussion modules, which allow users to easily exchange user experiences and suggest specific modification opinions.

In the six-month test conducted from October 2017 to March 2018, we rectified various bugs in the virtual laboratory based on feedback. In the return visit to the users, they all agreed that the virtual laboratory software has better performances in scene perception, experimental interaction, ease of use, and versatility, and can adapt to the needs of students and researchers at different levels.

5. Research conclusions

Chemical virtual laboratory is an important measure to improve the quality of chemistry teaching and solve the contradiction between supply and demand in chemistry laboratories. This paper used computer simulation technology and VIRTTOOLS platform as a basis to design a virtual chemistry laboratory software, which will be applied to specific experimental scenarios, and in the virtual laboratory application feedback, it received good comments. The specific findings of this paper include the following aspects:

- (1) The construction of the chemical virtual laboratory includes the selection of the construction mode, the selection of development tools, the determination of the development technical route, the interaction design, and the specific construction. The design fully takes into account the virtual laboratory's characteristics of experimental scene perception, experimental interactivity, ease of use, and versatility.
- (2) The selection of virtual laboratory construction mode is directly related to the perception of the experimental scene and experimental interactivity. In the four existing construction modes (including jumping mode, process mode, playing/viewing mode, and scenario mode), this paper believes that the scenario mode can best meet the requirements, and the virtual laboratory designed basing on the scenario mode can also best restore the real scene of the chemistry laboratory.
- (3) The selection of development tools has an important influence on the ease of use and versatility of the virtual laboratory. This paper uses VIRTTOOLS as a development platform, combined with PHOTOSHOP, 3D MAX and other specific development tools in the development process, and it has great advantages in ease-of-use and versatility.
- (4) According to the feedback of the virtual laboratory designed in this paper, based on its good performance in experimental scene perception, experimental interaction, ease of use, and versatility, the virtual laboratory can be promoted in a wider range.

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