Design and Implementation of virtual simulation experiment platform for computer specialized courses

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Abstract. For the practical teaching of computer specialized courses in colleges and universities, this study proposes the construction method of virtual simulation experiment platform based on OpenStack, Docker, Seafile and Raspberry Pi, and on this basis, deeply discuss the design and implementation details of the course experiment. The construction and application of virtual simulation experiment platform change the traditional teaching method fundamentally, reduce the cost of laboratory construction and management, which have important reference value to realize the remote experiment teaching. The virtual simulation experiment platform is composed of four parts: virtual machine, application container, cloud storage and client, which can meet the daily teaching needs, cultivate students' interest in learning, and improve their innovation ability.

1. Introduction

Practical teaching is an important part of computer specialized course and an important means to increase students' project experience and cultivate application-oriented engineering talents [1]. Traditional practical teaching is usually arranged in a dedicated computer room, where students learn by operating a physical computer. However, this teaching mode has the following disadvantages: (1) The construction and management of the computer room requires a large amount of human and material costs, including software installation, system release, computer and network maintenance, and so on. (2) Physical computer can’t fully meet the needs of practical teaching. Due to the limitation of system restore card, students can neither install software by themselves nor save phased achievements. (3) With the development of big data, cloud computing and other technologies, more than one computer is needed to build the experimental environment, while the traditional computer room can’t meet the experimental conditions [2]. Aiming at the above problems, this paper mainly studies the construction of virtual simulation experimental environment for computer specialty courses and the design of relevant experimental contents [3].

Virtual simulation technology is the product of combining today's mainstream computer technology with flexible and easy-to-use innovative software and modular hardware. With its high cost performance and good openness, it has been widely used in computer-related teaching, experiment and research [4]. By providing the same hardware and software equipment as the real production environment, the virtual simulation experiment platform can enhance the universality, flexibility and practicality of teaching and effectively improve students' practical ability [5]. In addition, it also strengthens the function of the laboratory, making it easier to maintain and upgrade
the laboratory. Interactive teaching and distance education can be carried out through network operation to expand the teaching scale.

The relevant work is organized as follows: Section 2 describes the construction technology of virtual simulation experiment platform. The details of the virtual experiment design for the course practice link are contained in Section 3. Section 4 summarizes the overall conclusions and further work.

2. Virtual Simulation Experiment Platform

In order to meet the needs of cultivating computer talents, college computer courses have been reformed to keep up with the current mainstream computer technologies, including big data, internet of things, cloud computing and so on. The practical teaching links also put forward higher requirements for experimental equipment, which usually requires multiple equipment to work together. However, the current computer laboratory cannot meet such an experimental environment. The virtual simulation experiment platform constructed in this paper is not aimed at a certain computer specialized course, but takes into account the experimental requirements of most courses to build a common virtual simulation environment. The products provided by this platform are virtual machines, application containers and cloud storage space for files, which can meet the needs of practical teaching in computer specialty; according to its own syllabus, each course should reasonably design specific experimental content under the virtual environment.

This platform uses OpenStack to provide virtual machine, Docker to provide application container, and Seafile to provide cloud storage service, and uses Raspberry Pi as the client, as shown in Fig. 1.

2.1. OpenStack

OpenStack is an open source cloud computing management platform project that provides scalable, flexible cloud computing services for both private and public clouds. The goal of the project is to provide a cloud computing management platform that is simple to implement, scalable, rich, and unified in standards. It covers network, virtualization, operating system, server and other aspects, and provides compute, object storage, image service, identity service and other 10 core projects and services [6].

In the virtual simulation experiment platform, OpenStack is mainly used to provide virtual machine, and the architecture of 3 control nodes and 4 computing/storage nodes is adopted. According to the actual situation, this experimental course adopts small class teaching, each class has a maximum of 40 people, and the maximum is 3 classes at the same time. To ensure the smooth running of the course experiment, each virtual machine needs to allocate 4G memory, 1-cores CPU and 500G disk space. At the same time, each virtual machine needs management overhead of 1G memory and some CPU. In order to satisfy 120 virtual machines to run at the same time, a total of 640G memory, 128-core CPU
and 64T disk space are needed. For this purpose, four Dell R740 servers are used as compute/storage nodes, each server is expanded to 160G memory, two 10-core 20-thread CPUs, and 16T disk storage. Dell R740 servers are also used for the three control nodes, as they only need to be responsible for the control and management operation of Openstack, the computing resources required are limited and the hardware configuration is reduced, each server only needs 64G memory, two 10-core 20-thread CPUs, and 2T disk storage. All the seven servers are interconnected through the ten-gigabit optical switch. Each server needs 4 network cards, and the bandwidth of at least 2 network cards is guaranteed to be ten-gigabit. The corresponding network cards of each server are interconnected through the VLAN of switch, respectively used for management network, computing network, control network and upper network.

At present, the virtual machine can provide Windows, Ubuntu and CentOS operating systems to meet the needs of experimental courses [7].

2.2. Docker
Docker is an open source application container engine that allows users to package applications and dependencies into a portable image for distribution on any popular Linux or Windows machine. Docker is an open platform for developing, delivering, and running applications, which separates applications from the infrastructure to deliver software, test, and deploy code quickly, greatly reduces the latency between writing code and running code in production [8].

It takes more computing resources to provide OpenStack-based virtual machines, and docker is lightweight and fast. Docker provides a viable, economical, and efficient alternative to virtual machines, and it can use limited computing capabilities to achieve more virtual services. Docker is well suited to high density environments and small and medium-sized deployments that can be done more with less resources.

Three Dell R740 servers are used for Docker virtualization, each server is configured with 64G memory, two 10-core 20-thread CPUs, and 4T disk storage, which are mainly used to provide Apache, Tomcat, Nginx, MySQL, Redis and other services.

2.3. SeaFile
One of the main problems in the traditional computer room is that the phased achievements of students can’t be effectively saved due to the system recovery card. Virtual machine and application container cannot allocate one for each student due to the limitation of computing resources. In order to solve this problem, this paper proposes a cloud storage scheme. Seafile is a safe and high-performance cloud storage software, providing all the functions of mainstream cloud disk products, including file synchronization, file sharing and so on. The Seafile server supports Linux, Windows and Raspberry Pi, the client supports Mac, Linux, Windows, Android and iOS, and also supports the form of web page to manage and access [9].

In the virtual simulation experiment platform, the cloud storage based on Seafile mainly provides two main functions: one is to complete the integration with OpenStack and Docker system, which is used to save the image files of the student virtual machine and application container, facilitate the storage of phased learning results, and realize the restoration operation of the system and application; the second is to provide the function of file server, open an account and permissions to save temporary files for each student. Three Dell R730 servers serve as cloud storage servers. The disk capacity of each server is expanded to 48T, a total of 144T, which is used to provide services to 10,000 teachers and students in the university.

2.4. Raspberry Pi
In order to realize the operation of virtualization products, the experimental platform conducts in-depth research on client access technology and realizes the integration of Raspberry Pi and display, which greatly facilitates the use of students and effectively reduces the cost of equipment management and maintenance [10].
Raspberry Pi is a micro-computer mainboard based on ARM, using SD/Micro-SD card as memory/hard disk. There are 1/2/4 USB interfaces and a 10/100 Ethernet interface around the card mainboard, which can connect keyboard, mouse and cable, as well as TV output port for video analog signal and HDMI HD video output port. All of these components are integrated into a mainboard board that is only slightly larger than a credit card, and it has all the basic functions of a PC, such as spreadsheets, word processing, playing games and playing high-definition videos, simply by connecting the display and keyboard.

There are two main ways to access virtual machine and application container: remote desktop and SSH connection. Using raspberry Pi to replace the traditional physical machine not only saves a lot of cost, but also can meet the experimental needs of computer courses. The above four parts constitute the basic framework of the virtual simulation experiment platform. After nearly a year's use and improvement, the platform has attracted more and more experimental courses to use, and achieved good teaching effect, which has been unanimously recognized by teachers and students.

3. Course Experiment Design

With the development of computer technology, the requirement of experimental equipment is higher and higher in practice teaching link, and a single physical computer usually can't meet the needs of actual teaching. In traditional teaching methods, the same notebook or desktop is usually used for program development, testing, deployment and other work, which leads to students' unclear understanding of the overall structure and operation principle of homework. Since the development environment, test environment and production environment all use the same computer, students can’t deeply understand the basic concepts of network, firewall, port, client and server and so on, and cannot integrate and reconstruct knowledge of multiple courses of computer specialty. Especially with the popularization of cloud computing, cloud storage and other products, most computer companies have given up the way of buying physical machines. In order to make the talents cultivated by colleges better adapt to the needs of employers, the practical teaching links must also make corresponding changes.

By using the virtual simulation experiment platform and rationally designing the practical teaching links of the course, the above problems can be solved to a great extent. Taking our school as an example, the design of computer major courses and virtual experiment links is shown in Table 1.

| Course Name                        | Virtualization Requirements | Software Requirements |
|-----------------------------------|-----------------------------|-----------------------|
| (1) Embedded System               | Application Container (1)   | QEMU                  |
| (2) Development of Embedded System Application | Application Container (1) | Ubuntu                |
| (3) Introduction to Internet of Things | Virtual Machine(1)         | Jupyter Notebook      |
| (4) Python Programming            | Virtual Machine(1)         | Ubuntu                |
| (5) Digital Image Processing      | Virtual Machine(1)         | Ubuntu                |
| (6) Data Mining Technology        | Virtual Machine(1)         | Ubuntu                |
| (7) Artificial Intelligence       | -                           | -                     |
| (8) Web Front-End Development Technology | Application Container (1) | Nginx/Apache         |
| (9) JavaWeb Development Technology | Virtual Machine(2)         | Nginx/Apache          |
|                                  | Application Container (1)   | JDK, MySQL            |
| (10) Software Development on Mobile Device | Application Container (1) | JDK                   |
| (11) Software Testing Technology  | -                           | -                     |
As can be seen from the table, most of the course experiments can be completed with the help of virtual simulation experiment platform, which can’t only improve the management level and efficiency of the laboratory, but also provide better experimental environment for students and achieve better teaching effect. Next, this paper takes “JavaWeb Development Technology” and “Embedded System” courses as examples to elaborate the course design of the practice link.

3.1. JavaWeb Development Technology

This course is divided into two parts, namely, Web front-end (browser) technology and Java back-end (server) technology. In the traditional teaching method, a student's notebook assumes all the roles, both as a development machine and as a server. Because the physical machine in the machine room cannot preserve the phased results, it is often not used. This can lead to students not understanding the overall architecture and operating principles of a project deployment.

In the virtual simulation experiment, the student's notebook is used as a development machine, and the platform will provide two virtual machines and an application container for the configuration of the server environment, one virtual machine for the deployment of the front and back end projects, another virtual machine for the file server, and the application container for the provision of MySQL database services, as shown in Fig. 2.

![Diagram](image)

Figure 2. Design of virtual simulation experiment for JavaWeb course

With the support of virtual simulation experiment environment, students can better understand the operation principle of B/S architecture project. Accessing projects over the network requires configuration of firewalls, IP addresses, ports, and other environments that cannot be learned from a single notebook. As for students' temporary phased achievements, it can be saved to the SeaFile file server by image file of virtual machine or application container, so as long as the system is restored in the next experiment, it can continue the unfinished experimental content.

3.2. Embedded System

The experiment part of this course traditionally adopts Linux experiment box. In order to enable students to have a deeper understanding of the working principle of embedded operating system, the platform adopts Docker application container to simulate Linux experiment box. By installing the QEMU emulator in the application container, all experiments based on the Linux laboratory box can be completed and students can better grasp the basic principles of operations such as cross-compilation. In addition, application container based on Docker requires very limited computing resources, so the server does not need high configuration, which can save a lot of experimental resources.
4. Discussion and Conclusions

At present, the virtual simulation experiment platform has been put into use for three semesters. There are altogether eight experimental links involved in the use of the platform. It has been unanimously recognized and highly appraised by teachers and students, which has improved students' application ability and trained computer professionals. In addition, the platform also puts forward new development mode and ideas for the construction of the laboratory, which saves a lot of management and maintenance costs and is worthy of further promotion.

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