Establishment and Application of MCU Virtual Simulation Experimental Environment Based on Cloud Server

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Abstract: With the influence of COVID-19, many universities require that the teaching and learning process should be switched promptly between online mode and offline mode. That brings challenges for teachers to teach MCU related courses requiring the integration of theory and practice. To satisfy the requirements of MCU related courses, the MCU virtual simulation experimental environment is proposed and established with the cloud server and Microsoft's Remote Desktop software, Proteus software, STM32CubeMX software and Keil MDK software. The experimental environment allows many students to log in and do MCU virtual simulation experiments from anywhere using their devices, such as smartphones, tablet computers, laptop computers and desktop computers. The proposed environment was practically established and used in online MCU courses. And the practice has proved that the experimental environment runs well and meets the requirements of online MCU courses. The proposed experimental environment is easy to establish and could provide a good reference for other online courses.

1 INTRODUCTION

In recent years, due to the impact of the new crown epidemic (COVID-19), courses in many universities or colleges should be taught online from time to time. The online teaching brings challenges for teachers to teach the courses that require practical operation. How to build suitable experimental environments for students in online courses? This is a practical problem that many teachers have encountered in online teaching process.

The fast development and application of cloud computing technology in recent years provide new approaches for online teaching. There are some researches about teaching and learning systems based on cloud computing services. Literatures (Faruk 2015, Christopher 2013, Omar 2021) have proposed a variety of education system architectures based on cloud computing services. These studies provide good references for the construction of online teaching and learning environment.

In practical online teaching and learning, many software applications can be used, such as Superstar Learning Link, Rain Class (Wang 2021), Tencent Meeting, Ding Talk etc. These software applications often use cloud services, 4G/5G communications, the Internet, Wi-Fi and other related technologies. Based on these applications, students and teachers can be connected through the Internet for teaching and learning activities. These applications generally satisfy the requirements of teaching and learning about theoretical parts in many courses.

And for the practical operation parts in many courses, these applications do not provide suitable approach. When using those applications, to fulfil practical teaching content, many teachers provided the learning videos about practical operation processes, or demonstrated the operational processes by live webcast. In those cases, most students who didn't have practical equipment could not do practical operation. The teaching and learning effects were poor.

In order to improve online teaching and learning effects, some enterprises and universities have put forward several virtual simulation experiment platforms applying virtual reality, augmented reality and other related technologies (Wang 2019, Wang 2019, Cheng 2020, Wang 2022).

These virtual simulation experiment platforms provide better practical operation and training environments, and are suitable for online or offline teaching and learning. However, the constructions of these virtual simulation experiment platforms are relatively complex and expensive, and often require long construction periods.

To quickly meet the demands of online teaching and learning, and aiming at the requirements of MCU courses, a virtual simulation experimental environment is proposed and established based on cloud server. And the Internet and several software applications are used in the environment.

2 THE BASIC PLATFORM OF MCU VIRTUAL SIMULATION EXPERIMENTAL EVIRONMENT

The cloud server is the core of the platform, and other four different terminal devices connect to the cloud server through the Internet, as shown in Figure 1.

The cloud server is a kind of reliable and scalable cloud computing service, and can provide multiple functions that the physical server has (Shi 2020). The cloud server has virtualized CPUs, virtualized memories, virtualized hard drives, the Internet network interfaces and related resources. The user can select the proper specifications of a cloud server and install Windows Server operating system in the cloud server. The Windows Server operating system supports remote desktop access function. And other devices can remotely log in to the cloud server using RD Client software that will be introduced in the following part.

The laptop computer with Windows operating system can be connected to the Internet through Wi-Fi, or wired Ethernet cable, or the wireless Internet card and many other methods. It has keyboard and touch pad. And a mouse is useful for students to draw MCU system diagrams. The Windows operating system that supports RD Client software should be installed in the laptop.

The desktop computer can be connected to the Internet through wired Ethernet cable, or Wi-Fi, or the wireless Internet card and many other methods. The Windows operating system that supports RD Client software should be installed in the desktop computer.

The tablet computer has been widely used in recent years. The tablet computer usually accesses the Internet through Wi-Fi. And most of tablet computers have the touch screens, but don't have mouse and keyboard. However, many tablet computers support mouse and keyboard with
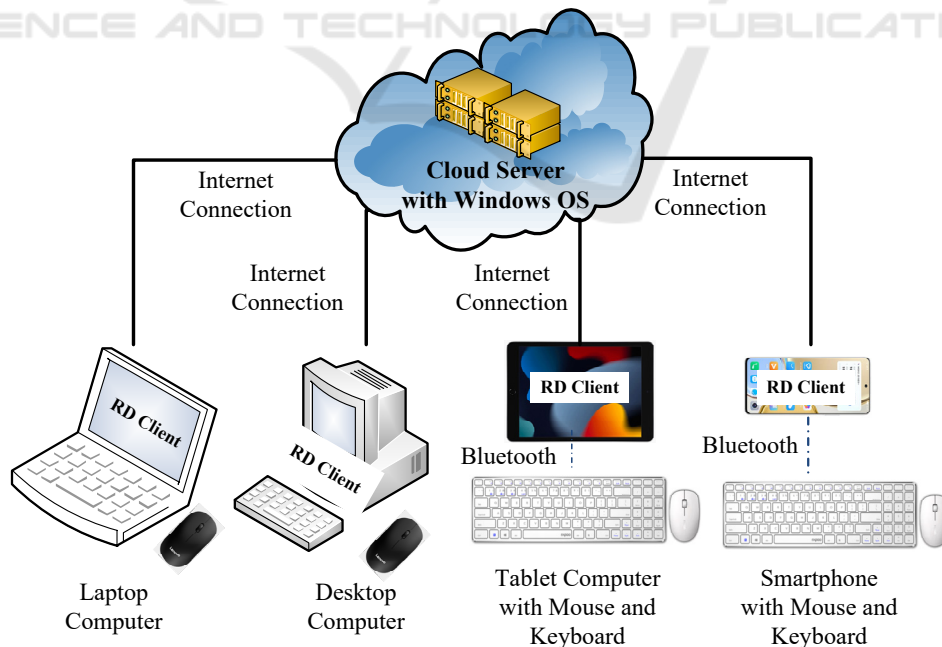

Figure 1: General view of basic platform of the virtual simulation experimental environment

Bluetooth communication function. In order to better meet the practical operation, the tablet computer is equipped with mouse and keyboard with Bluetooth. The mouse and keyboard are connected to the tablet through Bluetooth communication. In this way, the tablet computer has two human-computer interaction modes. One is to use the touch screen and the other is to use the mouse and keyboard.

The smartphone is frequently-used mobile terminal device. The students who do not have laptop computer, desktop computer and tablet computer can only use smartphones in the online class. The most of smartphones do not have mouse and keyboard, but support mouse and keyboard with Bluetooth communication. Consequently, it is possible to configure a smartphone with mouse and keyboard with Bluetooth communication. The mouse and keyboard can be connected to the smartphone through Bluetooth communication. And then the smartphone has two huma-computer interaction modes. One is to use the touch screen and the other is to use the mouse and keyboard.

The above four terminal devices communicate with the cloud server through the Internet. And to remotely log in to the cloud server, the proper RD Client software application should be installed in each terminal device.

RD Client software application was developed by Microsoft company. It uses remote desktop technology. The remote desktop technology adopts network communication technology and can enable the local computer to log in to the remote computer. And after successful login the user can operate the remote computer in the local computer and the image of the remote computer's desktop is real time displayed in the local computer's desktop (Li 2022, Wu 2020). There are different versions of RD Client software application that can run in multiple operating systems, such as Windows, Linux, iOS, Android and so on (Hao 2022). The proper versions of RD Client software application should be selected and installed in above four terminal devices. And then students can use RD Client software in their devices to remotely log in to the cloud server and operate it.

The core of the basic platform is the cloud server. And the cloud server has strong elastic computing and processing capacity and network connectivity, and allows many devices to log in at the same time. And meanwhile it is quick to increase or reduce the virtualized resources of the cloud server, such as the number of virtualized CPUs, the capacity of virtualized memory, and the capacity of virtualized hard disk according to the actual demands.

3 DEPLOYMENT AND CONFIGURATION OF SOFTWARE TOOLS

The content of MCU related courses usually include the design and drawing of schematic diagrams, the program design, coding and debugging, the comprehensive debugging of hardware and software. Based on the above platform, three software applications, Proteus, STM32CubeMX and Keil MDK are installed and deployed in the experimental environment.

The Proteus software is used to design, draw, simulate the MCU system circuits (Meng 2021, Chen 2009, Tan 2018). And the version of Proteus 8 supports simulation of the series of STM32F1 and STM32F4 MCUs, and is installed in the cloud server.

There are several MCU program software applications. Keil MDK is one of MCU program software application and is generally used in lots of enterprises and universities (Lian 2017). And Keil MDK is installed in the cloud server.

In recent years, STM32CubeMX software has been launched. The software provides the graphical approach to configure the series of STM32 MCUs, and can automatically generate configuration program codes that can be directly used in Keil MDK software (Chen 2019). With the help of STM32CubeMX, the program development of STM32 MCUs is becoming easer for students to learn. The STM32CubeMX software is installed in the cloud server.

The installation and deployment of the above three software applications in the cloud server are similar with that in the physical computer, and are not introduced here.

After Proteus, STM32CubeMX and Keil MDK are successfully installed in the cloud server, and students can remotely log in to the cloud server in local devices using RD Client software, and use three software applications to complete simulation experiments in MCU courses.

To permit many students to log in at same time, the multi-user login configuration of the Windows Server operating system should be set and the login username and password for each student should be created.

When using three software applications to do MCU system experiment, the main process is as the following.

1) Design and draw simulation schematic diagram of MCU system in Proteus software.

2) Configurate the STM32 MCU using STM32CubeMX software through the graphical approach.

3) Automatically generate the project codes that Keil MDK supported in Proteus.

4) Open the project codes in Keil MDK, and edit, debug codes, and create the Hex file.

5) Add the Hex file to simulated MCU in Proteus and run the simulation schematic diagram in Proteus.

6) According to run results to check whether the design is correct and then modification of codes or diagram might be needed.

4 THE PRACTICAL APPLICATION OF THE SIMULATION EXPERIMENTAL ENVIRONMENT

In online MCU courses the experimental environment was established and used in practical teaching and learning processes. In the practical environment, the ECS (Elastic Compute Service) from Alibaba Cloud was selected as the cloud server, and its main resources are illustrated in the following Table 1. In the Windows Server operating system of the cloud server, the multi-user login configuration was set and permitted. And then multiple students could remotely log in to the cloud server and do simulation experiments in online MCU courses.

Table 1: Main configurations of the ECS instance.

Item Name	Content
Location	Beijing
vCPU	4 cores
Memory	16GB
Architecture	X86 computing
Category	General
Operating System	Windows Server 2019
System Hardware	Enhance SSD, 40GB
Network Bandwidth	5M
Network Configuration	Internet Public IP

Proteus 8.0, STM32CubeMX 6.2 and Keil MDK5 were installed in the cloud server, as illustrated in the following Figure 2.

In practical online MCU courses there were fourteen students. It is found that the terminal devices all students used had diversity. The four types of terminal devices were all included. And the students installed
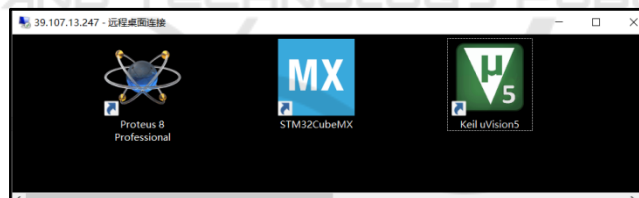

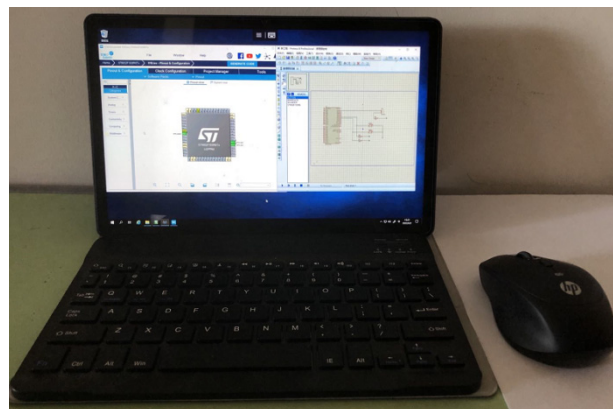Figure 2: Software installed in Cloud Server

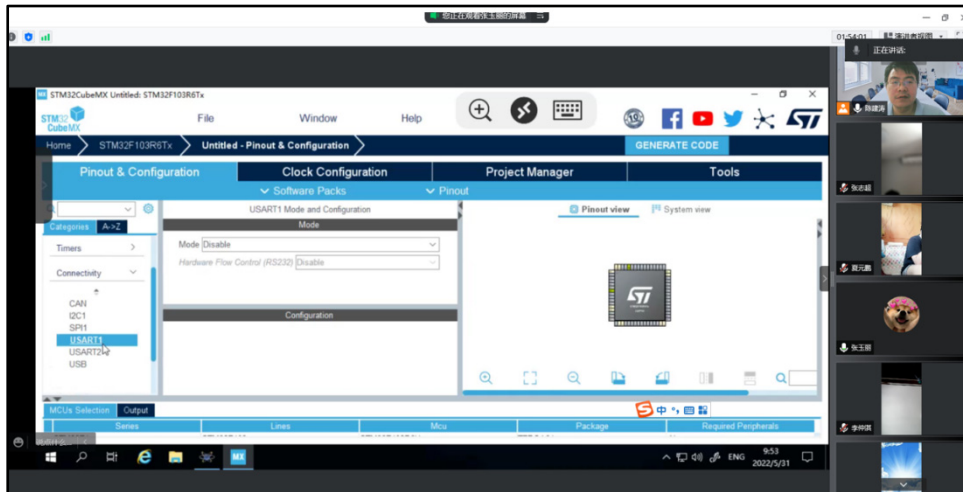Figure 3: Tablet Computer used in online MCU course

Figure 4: Smartphone used in online MCU course

the proper RD Client software in their devices and configured keyboard and mouse if needed. In the Figure 3 the tablet computer the student used in online MCU course is shown. In the Figure 4 the smartphone the student used in online MCU course is shown.

In practical online MCU courses, using the environment and with STM32F103 as the core MCU, the following experiments were fulfilled, LED control, Key input, Digital tubes, Key detecting with interrupt, LED delay control with timer, USART communication and Motors control.

During classes, in one short time when multiple students run the simulations, several processes of Proteus software application were quit suddenly. By testing it was found that the number of virtualized CPU and the capacity of virtualized memory of the cloud server were not enough. After increasing CPU numbers and memory capacity the problem was solved.

5 CONCLUSION

Under the influence of COVID-19, the demands of online teaching and learning have soared. It is worth to research and explore appropriate approaches for online teaching and learning. To fast satisfy the requirements of online MCU courses, the virtual simulation experimental environment is built using the cloud server, RD Client, Proteus, STM32CubeMX and Keil MDK. The cloud server with Windows Server operating system is the core, and the RD Client and the Internet are the key. The students in different geographical locations can

remotely log in to the cloud server in four different types of terminal devices using RD Client and the Internet, and operate Proteus, STM32CubeMX and Keil MDK software applications to fulfil the MCU related simulation experiments.

Based on the practical establishment and application of the environment, it is proved that the environment is easy to build and can stable run and satisfy the main requirements of online MCU courses. And the environment can provide a good reference for other online courses.

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