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# Research on Virtual Simulation Experimental Teaching of Computer Composition Principle for Training System Ability

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**ABSTRACT**
On the basis of analyzing the existing problems in the experimental teaching of the current Computer Composition Principle course, this paper takes the training of computer system ability as the guide, draws lessons from the practical teaching reform experience of the domestic first-class university and introduces the virtual simulation experiment platform: Logisim. The in-class experiment projects and the extracurricular big homework project based on the simulation platform reasonably have been set up and good results have been achieved in developing students' systematic ability in practical teaching.

***Keywords:*** *Computer composition principle, Virtual simulation experiment, System ability training, Logisim*

## 1. RELATIONSHIP BETWEEN PRACTICAL TEACHING OF THE COURSE AND SYSTEM ABILITY TRAINING

The ability of computer system is to train students to master the methods of abstracting and solving problems from various levels and details. Cultivating students' computer system ability is to enable students to analyze and solve problems from a systematic perspective, and to have a systematic integrity and overall view, rather than cramming and accumulating knowledge points.

Computer system is a complex combination of software and hardware, which can be described by hierarchical model, including microprogramming level, general machine level, operating system level, assembly language level and high-level language level. Computer system ability training requires students to master the cooperative work and interaction mechanism of computer software and hardware. The teaching goal of computer composition principle course is to let students know the working process and operating mechanism inside the computer, understand the working principle, logic realization, design method of each functional component and the technology of interconnecting to form the whole machine, and help them establish the concept of the whole machine[1].

The goal of practical teaching of computer composition principle is to improve students' understanding of the composition principle of major components of computer system, master the flow direction of data information and control information, and control time sequence, so as to cultivate students' ability of designing, debugging and developing computer system. In the practical teaching of this course, students are directly required to design and debug the important functional components such as arithmetic unit, memory and central processing unit in computer system, and be familiar with the interconnection technology among the major components, and initially establish the whole machine idea. Therefore, the practical teaching of composition principle course can play a very good role in cultivating students' computer system ability.

## 2. CURRENT SITUATION OF PRACTICAL TEACHING IN THE COURSE

Some data show that [3], at present, the practical teaching of computer composition principle course in domestic universities mainly adopts one of the following two forms.

(1) Traditional experimental box form. In some colleges and universities, the practical teaching of this course is to connect the separating devices through

 

wires to form a small system, and verify the system function by toggling switches and observing signal lights. This method allows students to have an intuitive concept of logic devices, but the reliability of the experimental system is extremely low, the debugging workload is heavy, and there are too many force majeure factors in the experiment. Students are seriously frustrated in the experiment. This kind of experiment is mainly based on verification, which seems to be a "complex" system completed by hundreds of wires. The real design connotation is very simple, and it is difficult for teachers to guide and check the experiment; Because of the large consumption, high cost, heavy maintenance workload, high site requirements and slow replacement of the experimental box, it can’t meet the requirements of modern electronic system design.

(2) FPGA development boards form. Hardware design simulation is completed by using hardware description language, and debugging is carried out on the development board. The experiment focuses on design. The real hardware design method can stimulate students' interest in learning and improve their ability of hardware design. However, the experimental mode is limited by hardware conditions. It mainly uses the functional components provided by the experimental system to complete the simple design experiment, and the content is biased towards verification to a great extent, which has insufficient support for building the whole computer concept and designing CPU. In addition, the experimental process is tedious, which requires students to select circuit mode, set chip parameters and other processes, which are tedious and error-prone. It wastes a lot of students' time and affects the experimental results. Moreover, the flexibility of experiment is not enough. Because of the limited number of test chambers, students can only complete the experiment in the laboratory, which limits the time for students to experiment. For students, there is no flexibility in choosing time [4]. Another serious problem is the programming of hardware design. Students always feel that they are doing programming experiments instead of hardware design. It is easy for students to copy the software programming thinking, and it is difficult to establish the corresponding relationship between design and the underlying circuit. The digital circuit design method cannot be extended to the experiment, which makes students have little experience in hardware design [2].To change the default, adjust the template as follows.

Because the above two schemes are not ideal, it is difficult to achieve the goal of cultivating students' systematic ability. Therefore, by learning the advanced experience of other universities, we have adopted the virtual simulation software Logisim in the experimental platform of this course set up by our new big data major.

## 3. VIRTUAL SIMULATION EXPERIMENT TEACHING DESIGN FOR SYSTEM ABILITY TRAINING

### *3.1. Virtual Simulation Experiment Teaching Design for System Ability Training*

Logisim is a software about teaching simulation for CPU system design experiment. Its interface is simple, circuit simulation is intuitive, digital circuit design can be completed by simple operation, and its sub-circuit packaging function can facilitate users to build larger-scale digital circuits [5]. The characteristic of the software is to design the system by separating digital circuit modules and building schematic diagrams. This design method is beneficial to cultivate students' thinking of hardware design, and avoids the problems of too abstract hardware description language and programmed hardware design. The platform is easy to learn, easy to debug, zero in experimental cost, free of site and personnel requirements, easy to build complex digital circuit systems, and convenient for flexible design experiments. Figure 1 is a single-cycle hardwired MIPS CPU designed by using Logisim platform and schematic diagram. At present, hundreds of schools around the world have used this platform, among which CS61C course at Berkeley, California has been using this platform, and Beijing University of Aeronautics and Astronautics, National University of Defense Technology and Huazhong University of Science and Technology are also using this platform [3].

### *3.2. Experimental Content Design for System Ability Training*

#### *3.2.1. General Design Ideas*

In order to achieve the talent training goal of Big Data major in our university and cultivate students' systematic ability, we have followed the following design ideas in designing practical teaching content.

(1) Systematize the experimental system around the cultivation of system ability. The system ability training goal of MIPS CPU is decomposed into multiple unit experiments with progressive levels and from easy to difficult. In the early unit experiments of the whole experimental system, students are required to gradually build each functional component, and finally integrate the result components of each unit experiment into a complete CPU. In the process of learning step by step, let students gradually develop a system view, and strive to make most students reach a higher level of system design ability.

(2) Make the practical content and theoretical teaching closely combine and complement each other. Let the original boring theoretical knowledge in this

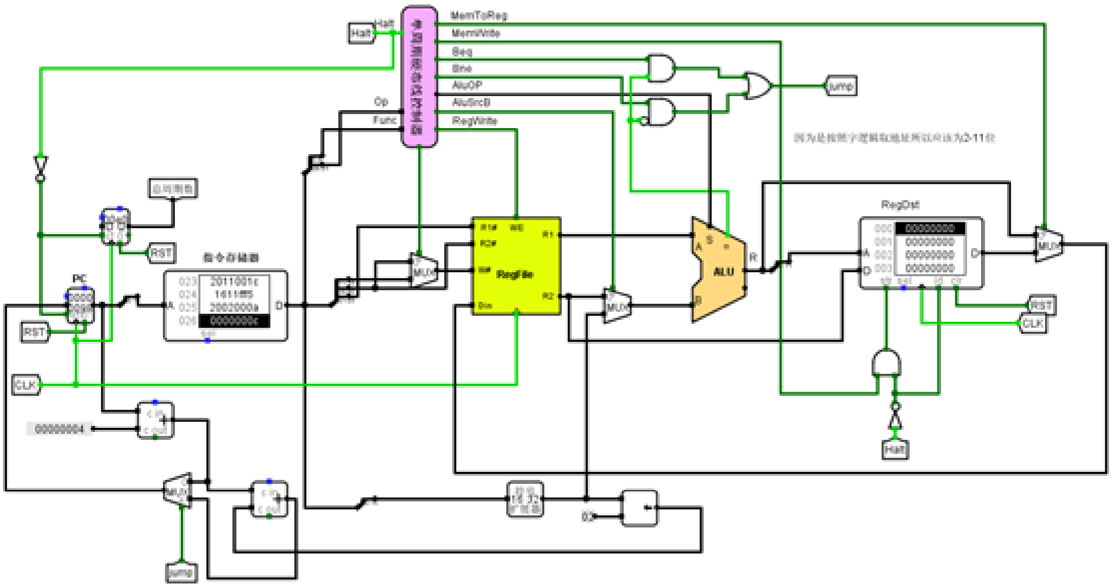


**Figure 1.** Single-cycle hardwired MIPS CPU designed in Logisim

course come alive in practice, and let students truly understand some difficult theoretical knowledge in theory course through practice; At the same time, the theoretical class also introduces the components and circuits to be used in the experimental class. Make the experimental course and the theoretical course complement each other, and really promote each other to achieve the goal of cultivating students' systematic ability.

(3) Extending from class to class, supplementing extracurricular experiments and major project assignments. Due to the limited experimental time in class, in order to give full play to the role of practical links in cultivating students' systematic ability, some meaningful extracurricular experiments are arranged for students to supplement the shortage of experimental time in class. At the same time, by requiring students to complete the major project assignments, and included in the experimental results, students' enthusiasm are aroused for extra-curricular study. They are encouraged to make full use of extra-curricular time to complete some more complex experimental projects that exercise the design level.

### *3.2.2. Arrangement of Experimental Items in Class*

After referring to the experimental tutorial [3,5] written by Zhihu Tan's course group of Huazhong University of Science and Technology, we arranged five in-class experimental projects. Among them, except for the first experiment, "Green man of Logisim on board", which is equivalent to the preparatory experiment, several other experimental projects focus on the system ability training goal, and complete the following experimental contents step by step, and finally realize the design and integration to get a complete MIPS CPU.

#### *3.2.2.1. Data Representation Experiment*

This experiment lasts for 4 class hours, and students are required to design and complete the corresponding circuit in Logisim to convert the internal codes of Chinese character coding into the corresponding location codes; Design a parity checking code circuit for 16-bit data coding, and be familiar with the function of transmission test circuit for 17-bit parity checking codes.

Through this experiment, students can master the coding rules of internal code, location code and font code in Chinese character coding; It can use the Chinese character coding principle to build and complete the Chinese character font code display circuit; Master the coding rules of parity checking code, and complete the experiments of even check coding, error detection and circuit testing in Logisim.

#### *3.2.2.2. Experiment of Arithmetic Unit Composition*

This experiment lasts for 4 class hours and requires students to design 8-bit controllable addition and subtraction circuit in Logisim. The 4-bit fast adder and 16-bit fast adder are designed and implemented by using 4-bit carry-ahead CLA74182 circuit. Unsigned 5-bit array multiplier is designed in Logisim.

#### *3.2.2.3. Storage System Experiment*

This experiment lasts for 4 class hours, and students are required to construct Chinese character library by capacity expansion in Logisim. A MIPS register file is constructed by using Logisim platform, and the register file is tested and checked for errors.

This experiment can enable students to understand the basic principles of bit expansion and word expansion in storage system, and enable students to solve the storage expansion problem of Chinese character library in the experiment by using relevant principles. Let students understand the basic concepts of MIPS register file, and be familiar with the use of Logisim components such as multiplexer, decoder and register. Students can finally build MIPS register files by using related components. And based on the register file, let students understand the working process of reading and writing data in RAM. An example of MIPS register file design is shown in Figure 2.

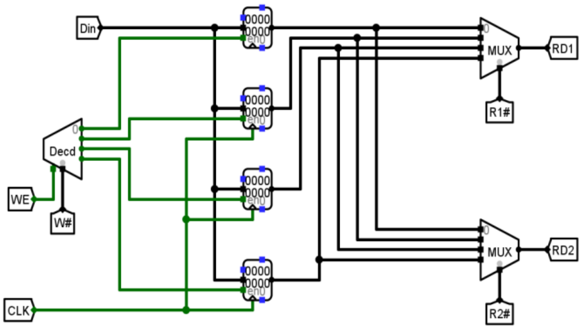


**Figure 2.** MIPS register file design example

*3.2.2.4. MIPS Processor Design Experiment*

This experiment lasts for 4 class hours. Students are required to build data paths and design hard-wired controllers by using the functional components completed in the previous experiments. Finally, the CPU of MIPS single-cycle hard-wired controller supporting simple instruction system is designed.

This experiment is a synthesis of previous experiments, which requires students to master the basic principles of controller CPU design. The design principle of hardwired controller can be used to design and implement the processor circuit with 8 core instructions in 32-bit MIPS single cycle in Logisim platform. The MIPS processor finally designed and implemented is required to run a bubble sorting test program and count the total number of cycles executed by the program. Through this experiment, students should master the general process of MIPS single-cycle CPU design and deepen their understanding of CPU controller. A CPU design example of MIPS single-cycle hardwired controller is shown in Figure 1.

### *3.2.3. Extra-curricular Experimental Large-scale Homework to Further Train System Ability*

Because there is no curriculum design for the computer composition course of big data major in our university, and the experimental hours in this course are very limited, in order to better cultivate students' systematic ability, we extend the in-class experiment to extracurricular, and make use of students' extra-curricular time to arrange students to complete large-scale homework projects with more design and complexity than the in-class experiment projects.

At the beginning of the semester, we arranged the extra-curricular experimental assignments with the students, and asked the students to use the extra-curricular time to finish them step by step, and then submit their homework at the end of the semester. The content of the big homework is not limited to death, so that students can choose freely according to their own interests within the scope of Chapter 1 to Chapter 3 of the practical tutorial in literature [5].In this way, the unlimited content of large-scale homework can give students room to play freely. Some students with strong ability can complete several design experiments that they are interested in, which greatly cultivates students' design ability and is also a useful supplement to the in-class experiment system. Through the large-scale homework after class, students can have a more comprehensive and profound understanding of the whole computer system.

## 4. EFFECT OF TEACHING EXPLORATION IN THE SYSTEM ABILITY TRAINING

According to our designed in-class experiment content and extracurricular experiment assignment around the goal of system ability training, after several rounds of teaching exploration, from the feedback of students, our virtual simulation practice teaching reform has achieved good results.

First of all, the experimental content is progressive, from easy to difficult, which is helpful to gradually cultivate and improve students' systematic ability. Each experiment has clear requirements for the designated level that students must reach, so that students can gradually develop a system view in the progressive learning process, and finally most students can reach a higher level of system design ability.

Secondly, the gradual improvement of experimental difficulty makes students less afraid of difficulties, and the completion rate of each experiment is higher, which enhances the sense of accomplishment, implements the system ability training goal that this course should undertake, contributes to the achievement of inclusive education, and meets the requirements of computer engineering education certification.

Finally, the experimental content that requires students to do it themselves makes the boring theoretical preaching in the course vivid. In theoretical teaching, we also focus on experimental arrangements and introduce the knowledge and skills related to experiments in a timely manner; Make students more willing to take theoretical lessons, let practice feedback theory, and make students more aware of the importance of theoretical study. It also promotes them to actively learn theoretical principles.

## 5. CONCLUSION

Logisim virtual simulation experimental platform has simple interface and intuitive circuit simulation, and can complete digital circuit design through simple operation, so that students can concentrate more on understanding and applying the course knowledge. A series of virtual simulation experiments based on this platform are progressive in content, and students have a strong sense of accomplishment, which is very helpful to develop students' computer system ability.

As a core course to train students' systematic ability of computer majors, we re-planned the experimental content, platform and means of the course Computer Composition Principle around the experimental goal of developing systematic ability. However, the content and mode of these experiments are not perfect because the reform has only been carried out among 2 sessions of students. How to unify the experimental curriculum system and further plan the supporting experiments among the various chapters in the curriculum is a problem that needs to be further planned and improved in future teaching.

## REFERENCES

[1] Dongqin Li, Yong Xu, He Chang, et al. “On the practical teaching reform of computer composition principle from deepening system ability training”. Modern Computer. 2017.10

[2] Wei Chen, Zhengfa Liang, Yuhua Tang, et al. “Experimental exploration of computer principle course”. Computer Education .2014 (15).

[3] Diqing Hu, Zhihu Tan, Fei Wu. “Research on the Virtual Simulation Experiment Teaching for Prineiple of Computer Organization Course”. Journal of EEE. 2018, 40 (4).

[4] Xiongkai Shao, Zhiwei Ye, Yong Ouyang, et al. “Discussion on the teaching of computer composition principle based on system ability training”. Computer Education. 2018 (11).

[5] Zhihu Tan, Leihua Qin, Diqing Hu. Practical Course of Computer Composition Principle-From Logic Gate to CPU. Beijing: Tsinghua University Press, 2018.