

# Construction of Hierarchical Experimental System for Innovative Teaching of Automatic Control Principle

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## ABSTRACT

The automatic control principle is an important compulsory basic course in control engineering, electrical engineering, mechanical engineering, ship power engineering and other professional disciplines, and it is also a prerequisite course of control professional courses. One of the important goals of the teaching reform of the control course group is to change the traditional verification experiment teaching mode into the design and innovation experiment mode combined with the actual engineering control object, focusing on cultivating the students' innovation ability and practical ability, and improving the students' innovative idea of integrating theory with practice and leading the project scientifically.

**Key words:** *experimental teaching; automatic control principle; verification experiment; independent experiment*

## 1. INTRODUCTION

The course of "automatic control principle" is not only a professional basic course of automation, electrical engineering and automation, but also plays an important role in the curriculum design of nonelectrical majors of mechanical and marine engineering. The experimental teaching of this course is very important because of its strong engineering practicality. The corresponding experimental content is gradually deepening from experimental verification, comprehensive experiment to design experiment; the training requirements for students are from experimental ability, comprehensive ability, design ability to engineering ability<sup>[1]</sup>. Engineering ability refers to the ability of students to analyze and solve practical problems. The cultivation of engineering ability can not only rely on the limited curriculum design and graduation design, but should start to cultivate the engineering ability of college students in the experimental stage. Therefore, higher requirements are put forward for the teaching materials, contents and experimental forms of experimental teaching<sup>[2]</sup>.

## 2. THE COMPOSITION OF INNOVATIVE HIERARCHICAL EXPERIMENTAL SYSTEM

In order to meet the teaching requirements of basic courses (for undergraduates) and specialized courses (for senior undergraduates and postgraduates) of automation related majors in the whole university, the construction of innovative hierarchical experimental center will be carried out from two levels. As shown in Figure 1, the first level is for the whole school. The second level is the construction of "automatic control principle / computer control technology" undergraduate basic course teaching; the second level is the construction of "automation system" professional course teaching for all automation related majors in the whole university, as well as the laboratory construction required by senior undergraduate and graduate students to explore innovative practice, including "principle model control system" exploration and innovation laboratory. There are three professional automation laboratories, including the innovative design verification Laboratory of system simulation and automation engineering and the laboratory of artificial intelligence and intelligent control.

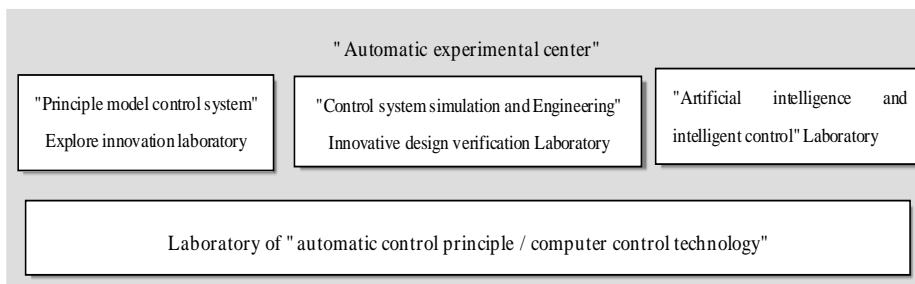


Fig. 1 Schematic diagram of "automatic experimental center"

The construction of "automatic control principle / computer control technology" laboratory is the foundation of the whole "Automation Experimental Center". It provides a wide range of applicable, optional and perfect experimental environment for the teaching of "automatic control principle / computer control technology" and other courses of automation related majors in the whole school.

On the basis of the laboratory construction of "automatic control principle / computer control technology", in order to cooperate with the professional course teaching and innovative experimental research of various automation related majors, the exploration and Innovation Laboratory of "principle model control system", and then the innovation design verification Laboratory of "control system simulation and automation Engineering" and "artificial intelligence and intelligent control" laboratory were constructed Professional automation laboratory. It provides a more targeted and clear target background experimental environment for professional automation course teaching, and also provides innovation and design verification experimental environment for senior graduates and graduate students.

### ***2.1. Teaching system design of principle verification experiment***

"Course principle verification system" includes automatic control principle and automatic control technology. When selecting the course principle verification system, the principle of typicality, completeness and openness should be followed<sup>[3]</sup>.

For the "course principle verification system" of control principle, typicality refers to that the system is a typical system that can produce all kinds of principle verification experiments recognized in the industry; completeness means that the system experiment can cover all the experimental items of the control principle course; and the openness means that the experimental students can enter the system to conveniently design and verify the experiment.

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At present, the laboratory can carry out the following experimental teaching projects: (1) simulation study of typical links; (2) transient response and stability of typical systems; (3) frequency characteristics of control systems; (4) sampling system analysis; (5) state feedback; (6) a / D and D / a switching; (7) sampling and holding.

### ***2.2. Construction of virtual simulation experiment system for control courses***

#### ***2.2.1. Design of control system simulation experiment system based on MATLAB***

The traditional experiment of automatic control principle is completed on the control experimental device produced by some teaching instrument factories. The typical links such as proportion, integration and first-order inertia are composed of operational amplifier, resistance, capacitance and other simulators. In the experiment, the system is decomposed into series form of each typical link, and then the modules representing the corresponding typical links are connected in the simulation device, and the response and dynamic indexes of the system are observed through the oscilloscope. Although this kind of experimental method has a certain effect on cultivating students' practical ability and deepening the impression of classroom learning content, there are two limitations: (1) the experimental equipment is highly integrated, and the expansion performance is poor. Due to the integration of various typical links of the experimental device and the limited modifiable parameters, the experiment is mainly verifiable, and the operation is complex. (2) Drawing and calculation are complex. Automatic control principle is a relatively abstract theoretical course of automatic control major. Because the analysis of control system often involves the drawing and complex calculation of various analysis methods, students need to spend a lot of time and energy on drawing and calculation, which affects the mastery of control system analysis principle. As a result, the course is difficult to teach, and students' learning pressure is also great<sup>[5]</sup>.

#### ***2.2.2. Design of control system simulation experiment platform based on LabVIEW***

As a graphical programming software, LabVIEW has been widely used in the field of virtual instrument and engineering education in Colleges and universities. In addition to the basic functions of general programming languages, LabVIEW's unique module plug-in and toolkit can make users easily complete the programming of data acquisition, real-time system, FPGA device, control algorithm, system simulation and other applications. As the software core of virtual instrument technology, LabVIEW can maximize the function and efficiency of hardware<sup>[6]</sup>. Users can customize algorithms and functions to load on the hardware according to their different requirements. From the system point of view, LabVIEW can not only complete the development of individual devices, but also facilitate the integration of complex systems. As for developers, they only need to face the development language of LabVIEW. Therefore, whether from the perspective of development cost and development cycle, or from the future maintenance difficulty, LabVIEW

can not be replaced by other development environments Advantages: LabVIEW software interface is shown in Figure 2.

The site license mainly includes the following software

**Core Software**

- LabVIEW Core DVD
- LabVIEW PDS for Windows
- LabVIEW Control Design Toolkit
- LabVIEW Simulation Module
- LabVIEW System Identification Toolkit
- LabVIEW Digital Filter Design Toolkit
- LabVIEW Modulation Toolkit
- SignalExpress
- NI Multisim Evaluation
- LabVIEW PID Toolkit
- LabVIEW Fussy Logic
- LabVIEW Enterprise Connectivity Toolkit

**Application Area Software DVDs**

- Control & Embedded Systems DVD
- LabVIEW FPGA Module for Windows
- LabVIEW Real-Time Module (ETS)
- LabVIEW Real-Time Module (RTX)
- LabVIEW Execution Trace Toolkit
- Simulation Interface Toolkit
- MATRIXx
- LabVIEW State Diagram Toolkit
- LabVIEW Math Interface Toolkit
- LabVIEW DSC Module / LabVIEW
- LabVIEW PDA Module
- NI SoftMotion Development Module
- NI Motion Assistant
- LabVIEW PID Control Toolkit
- LabVIEW DSP Module
- NI Vision Development Module & Vision Assistant
- LabVIEW FPGA Module
- Advanced Signal Processing Toolkit
- Measurement Studio PID Control Toolkit

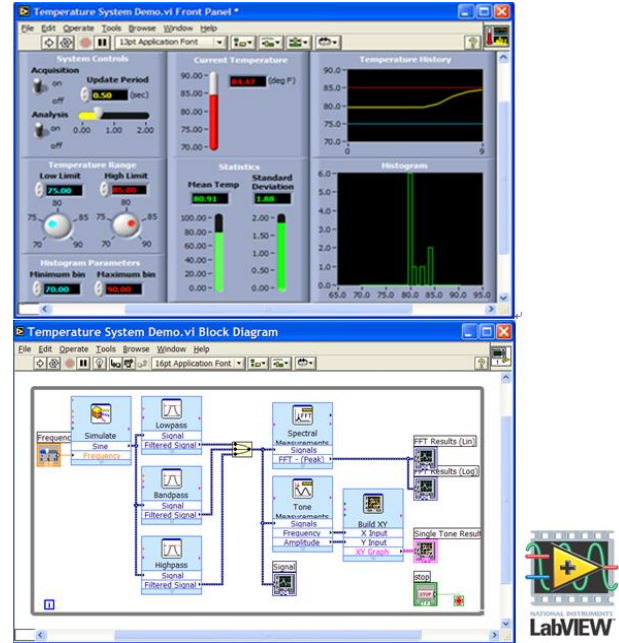


Figure 2 LabVIEW software interface

**2.3. Explore the design of innovative experimental teaching system**

In the process of experimental teaching of control theory course, it is necessary to reform the experimental content, enhance the laboratory strength, separate the experiment from the theoretical teaching, form an independent experimental teaching course, break the boundaries between the subject courses, and strengthen the connection between the experiments of various disciplines. It is required that the theory teachers should not only teach, but also guide and develop experiments. These measures greatly strengthen the strength of the laboratory, not only conducive to the cultivation of teachers' practical ability and the improvement of theoretical teaching, but also strengthen the communication between teachers. Secondly, professional teachers are required not only to be familiar with experimental equipment, but also to participate in the establishment of innovation laboratory, so that teachers can not only teach knowledge in books, but also know how to combine theory with practice, so that students can no longer see difficult, monotonous and Abstract book knowledge, which fundamentally mobilize students' interest in learning and practice, and improve students' interest in learning initiative<sup>[7]</sup>.

According to the existing experimental equipment in the automation technology laboratory, the open independent experimental projects such as inverted pendulum model and motor control model are developed. Students can use different control systems to carry out different experiments according to different experimental purposes, so as to give full play to students' creative ability, improve their ability to analyze and solve problems, and further deepen their

understanding and understanding of the course of control theory<sup>[8]</sup>.

Innovative experiment is that students can choose and design experiments according to their own hobbies and laboratory conditions. The original experiment was based on a certain theoretical course, without considering the relationship between this course and other courses. At the same time, due to the short experimental time, the experimental content and experimental steps are fixed, so many students are still confused after finishing the experiment step by step. The innovative experiment will be task-based, and teachers only need to put forward control requirements. As for how to achieve this requirement, students need to design by themselves, which greatly mobilizes the initiative of students. In order to make the newly designed experiments have greater flexibility and can take into account multiple courses, we have developed various robot innovation kits for the existing automation technology laboratory. The construction and control experiment of the robot. It serves for comprehensive practice of intelligent control, undergraduate graduation design and experimental teaching of graduate courses<sup>[9]</sup>.

Robot innovation laboratory can provide practice and training places for electrical and automation courses. Robot is a typical intelligent control and information system, which integrates computer software and hardware, embedded technology, image recognition, pattern recognition, automatic control technology, electronic design, sensor information fusion and artificial intelligence and many other advanced technologies, which is closely related to each professional direction of our department. The construction of robot innovation laboratory and the development of robot innovation practice can make students comprehensively use the theoretical knowledge of these courses, and through the guidance of teachers, they can design and build a "engineering project" (such as making an automatic carrying car project), and realize the function with programming. Such a "project-based curriculum" can improve students' practical ability and independent thinking and innovation consciousness, and cultivate high skilled talents with innovative spirit.

The robot innovation practice should reflect the cultivation of students' practical ability and practical innovation ability. The teaching robot equipment used in the laboratory has the following characteristics.

(1) Robot platform focuses on training students' practical ability. Students can quickly build a variety of robot configurations, and write a variety of robot control algorithms and strategies, give the robot intelligence, let the robot with the image of the shape and interesting action to show the various program algorithms and software skills students have learned.

(2) Robot platform needs modular design, which can support students' creative learning and practice. For example, students use modular robot kits to design and assemble robots of different shapes, such as bionic robot, intelligent car, robot dog, snake like robot, maze walking robot, simple humanoid machine and industrial manipulator. In order to better stimulate students' practical

interest, from simple imitation to the realization of self innovation.

(3) The teaching difficulty of robot course should be from simple to deep, guided by students' interest, and aimed at mastering skills and improving engineering quality. It provides an open experimental platform. Through teachers' teaching and students' experiments, students can understand and master how software and programs are reflected in the actual control and application of complex systems from the overall point of view, cultivate engineering literacy and exercise preliminary engineering skills. The difficulty of preliminary experiments should not be too large. The supporting experimental resources should pay attention to the guidance from the shallow to the deep, but the robot platform must be opened. It is easy to expand and experiment, which can provide a basis for later study and experiment.

### 3. CONCLUSION

Based on the detailed analysis of the research status of the control curriculum group and its independent innovation experimental system, we proposed to construct the independent innovation experimental system of the control class curriculum group by using the hierarchical thought, which organically combined the theoretical study of the control course with the engineering practice, so as to meet the experimental requirements of different educational levels, such as undergraduate and graduate students. The new attempt can fundamentally change the experimental teaching method of the course and further improve the students' practical and innovative ability. In the process of laboratory construction, we developed a set of "automatic control principle experiment teaching software based on MATLAB". The development of the software has brought great convenience to the teaching of automatic control theory. It can make students understand the content of automatic control theory intuitively and vividly, and play a good auxiliary role in the design of automatic control system. It can also save the investment and maintenance cost of experimental equipment. The functions of the whole system are divided into step response, pulse response, Nyquist diagram, Bode diagram and root locus diagram. At the same time, taking the existing "Creative Star" robot suite in the laboratory as the carrier, the construction of robot innovation practice teaching system has achieved satisfactory results.

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