



Design of Simulation Teaching System of Automatic Control System Course Based on MATLAB

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Abstract. In the simulation teaching of automatic control system courses, the traditional teaching system is limited by experimental equipment and resources, and the teaching effect is relatively poor. For this reason, the design of the simulation teaching system of the automatic control system based on MATLAB is proposed. Optimize the original teaching simulation system of the automatic control system course, based on this, establish the mathematical model of the automatic control system, describe the dynamic characteristics of the automatic control system operation process, determine the construction rules of the simulation teaching system, and use the virtual simulation laboratory Repeated training to train the simulation operation of automation equipment, combined with the dynamic characteristics of the operation of the automatic control system, construct a simulation teaching system of the automatic control system course. The experimental results show that the proposed MATLAB-based automatic control system course simulation teaching system has high teaching quality and high consistency and reliability, enabling students to understand the working principle of the automatic control system and master the design method of the automatic control system.

Keywords: MATLAB · Automatic control system course · Simulation design · Teaching system

1 Introduction

Simulation experiment teaching is one of the main experimental links in higher science and engineering schools. It plays an extremely important role in cultivating students' practical operation ability, problem analysis and problem solving ability; professional comprehensive experiment courses also shoulder comprehensive application. The basic knowledge and professional knowledge learned are the task of cultivating students' creativity [1]. At present, there are still some problems and shortcomings in the experimental teaching of automatic control system courses in various universities: First, the experimental device is composed of discrete devices such as transistors, resistors, and capacitors, and uses a proportional control method. The experiments done on this device are mainly confirmatory experiments, which have played an active role in cultivating

students' basic circuit analysis and practical ability [2]. However, the control method is single, the adjustable parameters are limited, and the experiment is not flexible enough to fully mobilize the subjective initiative of students. Second, it is very difficult to conduct experiments on the device to observe the dynamic process. Third, with the reform of education Advance, the enrolment scale continues to expand, resulting in insufficient experimental equipment and shortage of experimental resources [3]. New experimental methods and methods must be used to make up for these deficiencies and solve existing problems.

The popularization and promotion of computers have provided a good foundation for multimedia teaching and simulation. It is very beneficial to introduce simulation in experimental teaching. First of all, under the provided simulation platform, design experiments can be carried out. Students can flexibly change parameters, increase or decrease some links, and adopt different control methods. This will not only allow a deeper understanding of the experiment content, but also mobilize the creativity of students. Secondly, the simulation method can be used to relatively easily realize the observation of some dynamic characteristics and dynamic processes of the control system [4]. Third, through the combination of simulation and experiment, the efficiency of the experiment can be improved and equipment damage can be reduced. Students can simulate the experiment to be done first, and after fully understand the principle, then carry out the experiment and debugging of the actual device, so that the experimental hours can be compressed to solve the problem of insufficient experimental resources. By analyzing and comparing simulation results and experimental results, students can improve their ability to analyze and solve problems [5].

Aiming at the problem of poor teaching effect gain in the traditional teaching system, a MATLAB-based automatic control system course simulation teaching system design is proposed to solve the above-mentioned problems in the traditional teaching system. Drawing lessons from the overall concept of CDIO and the design ideas of integrated teaching system, construct a simulation teaching system of automatic control system courses. Enable students to choose related courses according to their own interests and hobbies, and promote the cultivation of students' personality and innovation ability.

2 Design of the Simulation Teaching System of the Automatic Control System Course Based on MATLAB

2.1 Design MATLAB Teaching Simulation

In order to achieve the real simulation of the object in MATLAB teaching simulation, MATLAB hardware and software systems should be used as much as possible. In addition to the control station and operating station, the actual MATLAB system also includes Field Bus Module (Field Bus Module) that provides interfaces for field sensors and actuators., Bus isolator, cabinet and power supply, etc. [6]. For simulation, field devices are replaced by mathematical models. MATLAB's control strategy, information management, and operation display functions are all completed in CP and WP. Other devices are only responsible for information exchange. Therefore, MATLAB teaching machine only needs CP and WP hardware and corresponding software system [7].

In the hardware structure of MATLAB teaching simulation designed, the trainer station plays the role of process model machine and network server at the same time, and the engineer station is mainly used for configuration and monitoring, so it can also be used as a control model machine [8]. In this way, the hardware structure is mainly composed of trainer station, engineer station, and operator station.

In the actual teaching site, the hardware connection between the MATLAB system and the power generation equipment is adopted, and each control target and sampling point corresponds to the field bus component FBM [9]. In order to ensure the teaching function of the system, the control system configuration software and screen configuration software are protected in the application software. When the operator configures the flow chart and control logic, the information applied is simulated from the appearance and configuration results. The influence of the model is consistent with the field configuration.

2.2 Establish a Mathematical Model of the Automatic Control System

In the course of automatic control system, it is mainly to analyze and understand the automatic control system. One of the first tasks of analyzing the automatic control system is to establish the mathematical model of the system, because it is necessary to understand the performance of simple systems or the performance of complex systems. Grasp the relationship between variables in the system. These relationships are described by mathematical equations, which are called mathematical models of the system.

The mathematical model of the system can be described from two aspects. The first is to study the steady-state operating conditions of the system. Under steady-state conditions, the parameters of the system are independent of time, and the mathematical equations that determine the relationship between the parameters of the system are algebraic equations. However, it is more important to study the dynamic equations of the system, because the control system itself is not static, its output always changes with changes in the input, and the system will also be subject to various disturbances that change over time. Therefore, the various variables of the system are not constants, but change with time. It can be seen that the mathematical equation describing the dynamic characteristics of the system includes not only the variables themselves, but also the rate of change or derivatives of these variables. Such mathematical equations are differential equations. Differential equations are one of the most basic characterizing the dynamic characteristics of the system. Mathematical equation.

When studying system characteristics, the concept of linearity is very important. When there is a linear relationship between the input variables and output variables of several devices, after connecting them in series, parallel or feedback mode, the relationship between the total input and output is also linear [10]. The linear system satisfies the principle of superposition, that is, when the linear system has more than two input variables, the output variable of the system is equal to the sum of the output variable changes caused by the independent action of each input variable [11].

However, the actual teaching process is often very complicated, and most parameters exhibit nonlinear characteristics. If this nonlinear relationship is accurately represented by nonlinear equations, it is extremely difficult to solve these differential equations. In order to simplify the analysis of the regulation system, in the teaching process, the

nonlinear system is usually approximated to linearization [12]. Under certain working conditions, when the system parameters change in a small range, the “small deviation method” is used to linearize some nonlinear systems. The so-called “small deviation method” is to use Taylor formula to expand the nonlinear function of variables into incremental expressions of these variables near the equilibrium point. Then omit the items higher than one increment to obtain an approximate linear function [13].

Assuming that the output y is a nonlinear function of the input x , $y = F(x)$, at the equilibrium point (x_0, y_0) , expand $F(x)$ into a Taylor series:

$$F(x) = F(x_0) + F'(x_0)(x - x_0) + \frac{F''(x_0)}{2!}(x - x_0)^2 + \dots \quad (1)$$

make:

$$\Delta y = y - y_0 = F(x) - F(x_0) \quad (2)$$

$$\Delta x = x - x_0 \quad (3)$$

then:

$$\Delta y = F'(x_0)\Delta x + \frac{F''(x_0)}{2!}\Delta x^2 + \dots \quad (4)$$

Since Δx is a small increment, the high-order infinitesimal term and remainder can be omitted to obtain an approximate formula:

$$\Delta y = F'(x_0)\Delta x \quad (5)$$

The above-mentioned linearization is performed under the assumption that the input and output variables change in a small range around the equilibrium point, and this precondition is in line with the actual situation in many control systems. If the actual variation of the system is large, the linear model with small deviation will have a large calculation error. For non-linear characteristics such as relays and gaps, it is not suitable to use the deviation method for linearization due to the inability to perform derivative calculations.

The application of digital computers has opened up a new way to establish precise mathematical models. The calculation speed of digital computer is fast and the precision is high. If necessary, hundreds of equations can be used to describe a complete system, but in most cases, people often use a low-order linear mathematical model to describe the operation of automatic control system. The dynamic characteristics of the process, because the low-order approximate model has sufficient accuracy when analyzing the control system, and the calculation workload is significantly reduced.

2.3 Determine the Principles of Constructing a Course Simulation Teaching System

In order to ensure the realization of the content and training objectives of the originally determined curriculum plan, the key is to determine an appropriate and reasonable organizational form for the curriculum plan. Adopting the CDIO concept, emphasizing the

real background environment of engineering practice, and emphasizing the life cycle activities under the engineering chain, this makes the design of the curriculum simulation teaching system not only to achieve the integration of knowledge, ability and quality training, but also the training of technical elements and non-technical elements. Integration and mutual support between theoretical knowledge must be realized. In view of this, the construction principles of the simulation teaching system of the automation control system course are mainly reflected in the following two aspects:

First, the organizational principles of the overall design. The overall design of the teaching system is mainly to solve the problem of how to integrate training objectives, theoretical knowledge content and practical links into the curriculum plan. According to the target value orientation determined by the teaching vision and syllabus, the curriculum plan under the CDIO concept chooses the most integrated curriculum simulation teaching model. This model is based on mutually supporting theoretical knowledge and a series of abilities or project links. Weft, warp and weft weave the two organically, realizing the combination of theory and practice, and the organic integration of knowledge, ability and attitude training.

Second, the organization principle of the content order of the teaching system. The content order of the teaching plan is the schedule arrangement of the students' learning, which mainly involves the order arrangement of the subject curriculum content and the ability teaching content. The schedule of subject teaching content can be established on the basis of the perfect subject content sequence in the past, while the ability teaching content sequence is difficult to be clear and can be formed in the specific design process of the teaching system.

2.4 Constructing a Course Simulation Teaching System

After determining the principles of constructing the course simulation teaching system, drawing on the overall concept of CDIO and the design ideas of the integrated teaching system, the construction of the automatic control system course simulation teaching system is shown in Fig. 1.

Based on the current problems in the teaching of automatic control system courses, too much emphasis is placed on the learning of professional courses, the training of students' hands-on ability is ignored, and the proportion of practical courses is low. Under the guidance of the CDIO concept, the automatic control system course simulation teaching structural elements. The following principles should be adhered to when setting:

The principle of combining theoretical teaching with engineering practice training. The design of the teaching system emphasizes engineering practice and increases the proportion of practical links. It does not mean that scientific theories are not important, but to return to the practical nature of engineering on the basis of theoretical knowledge. Students must have both solid scientific theoretical knowledge and Have the ability to solve practical engineering problems in a real environment.

Pay attention to the principle of profound professional basic theoretical knowledge. The CDIO model focuses on the learning of profound engineering technology basic knowledge. The design of the teaching system should focus on basic science and engineering science courses, set appropriate proportions, and provide necessary and systematic basic knowledge for professional courses, but at the same time ensure that it provides

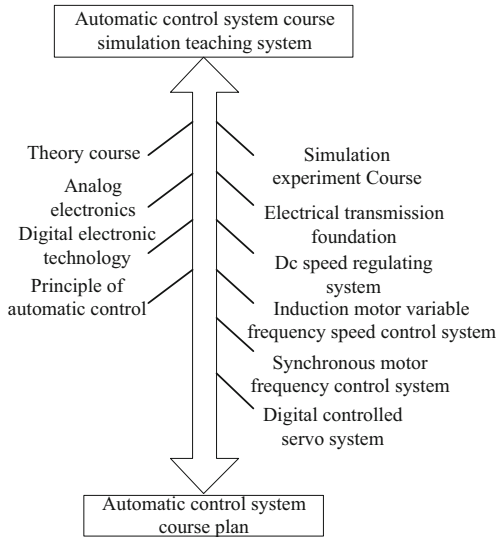


Fig. 1. Course simulation teaching system

engineering talent training. The necessary professional knowledge and professional skills training.

The principle of combining technical and non-technical elements. The teaching system should not only provide necessary technical education for the training of engineering talents, but also pay attention to non-technical education such as society, politics, economy, culture, and art, so as to improve students' humanistic and professional qualities, and cultivate their international vision and sustainable development. Philosophy makes it a modern engineer with both ability and political integrity.

Strengthen the principle of innovation and focus on the cultivation of students' personality. An appropriate proportion of elective courses should be maintained in the teaching system, so that students can choose relevant courses according to their own interests and hobbies, and promote the cultivation of students' personality and innovative ability.

Use the virtual simulation laboratory to repeatedly train the simulation operation of the automation equipment, and combine the dynamic characteristics of the automatic control system to construct the automatic control system course simulation teaching system. So far, the design of the simulation teaching system of the automatic control system based on MATLAB is completed.

3 Experimental Research on Simulation Teaching System of Automatic Control System Course

3.1 Experiment Preparation

In the experimental research of the simulation teaching system of the automatic control system course, various factors in the experimental process of the experimental variables

are clarified. In the experiment, the proposed MATLAB-based automatic control system curriculum simulation teaching system, the traditional DCS-based simulation teaching system and the fuzzy control-based simulation teaching system are used as independent variables to unify the experimental goals. The above three teaching systems are used for teaching. After the teaching course is over, the consistency reliability and teaching quality scores are calculated, and the pros and cons of the three teaching methods are compared based on the results. The dependent variables in the experiment are consistency reliability and teaching quality score.

The goal of the experiment is a freshman in a key university. In order to more objectively reflect the students' learning situation and effects, in addition to processing the data analysis of the students' pre-test and post-test, it is also necessary to analyze the students' learning data in the course to ensure the data consistency. The consistency reliability in the experiment is only for the performance of the students in the teaching process and the implementation process of the teaching system; the teaching quality score is for the comprehensive results of the students after teaching, which is the effect of the teaching system. In the comprehensive evaluation of teaching quality, the fuzzy evaluation method is used to obtain the comprehensive evaluation of teaching quality.

3.2 Determine the Evaluation Level of Teaching Quality

Suppose $U = \{u_1, u_2, u_3, u_4, u_5\}$ represents the scoring factor, and $V = \{v_1, v_2, v_3, v_4, v_5\}$ represents the n levels of the state of each scoring factor. In the experimental research of the simulation teaching system of the automatic control system course, 5 grades are set, as shown in Table 1.

Table 1. Interval table of different scoring levels

Rating level	Score interval	Description
I	100~90	Excellent
II	89~80	Good
III	79~70	General
IV	69~60	Pass
V	59~0	Failed

According to the score interval of different grades, after the evaluation, the fuzzy evaluation matrix G is established, and the obtained scores are normalized. Use g to represent the degree of membership to determine the fuzzy relationship G . The relationship between matrices G and g is as follows:

$$G = (g_{ij})_{4 \times 4} = \begin{pmatrix} g_{11}, g_{12}, g_{13}, g_{14} \\ g_{21}, g_{22}, g_{23}, g_{24} \\ g_{31}, g_{32}, g_{33}, g_{34} \\ g_{41}, g_{42}, g_{43}, g_{44} \end{pmatrix} \tag{6}$$

Use the synthetic factor of the fuzzy matrix to obtain a comprehensive evaluation matrix of all scoring factors:

$$W = U \times G = U(G_1, G_2, G_3, G_4) \tag{7}$$

The comprehensive evaluation value of teaching quality is calculated through the comprehensive evaluation matrix, and different teaching methods are compared and analyzed in combination with consistency reliability.

3.3 Consistency Reliability Experiment Results and Analysis

Consistency reliability refers to the measurement of whether there is the same result every time the same teaching system is used to teach the same object under the same conditions. Under normal circumstances, a consistency reliability of more than 75% is considered reliable and meets teaching needs. The calculation formula is:

$$\eta = \left[\frac{1 - (X - Y)}{(X + Y)} \right] \times 100\% \tag{8}$$

In the formula, X and Y respectively represent the test records of different teaching observers. The default condition is $X > Y$. Through the observation of the actual teaching process of different teaching modes by different observers, the observation results are recorded, and the agreement between the observers is calculated degree. The result is shown in Fig. 2:

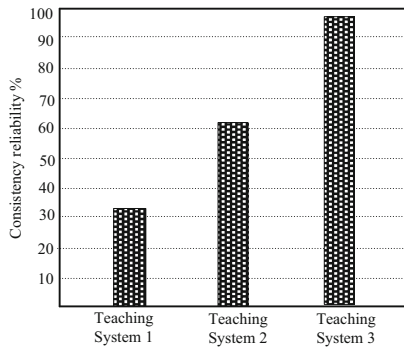


Fig. 2. Experimental results of consistency reliability of different teaching systems

The teaching system 1 shown in the figure is a simulation teaching system based on MATLAB, teaching system 2 is a simulation teaching system based on fuzzy control, and teaching system 3 is a simulation teaching system based on DCS. Comparing the results in the observation graph, it can be seen that the consistency reliability of teaching system 1 is 34.6%, the consistency reliability of teaching system 2 is 62.4%, and the consistency reliability of teaching system 3 is 97.6%. It can be seen from this the consistency reliability of System 3 exceeds the 75% limit, far exceeding the values of the other

two teaching systems. Therefore, it can be considered that in the consistency reliability experiment, the application of the MATLAB-based automatic control system curriculum simulation teaching system can better ensure the quality of curriculum teaching.

3.4 Teaching Quality Evaluation Results and Analysis

Considering that some teaching factors are affected by time, the teaching quality score is calculated in three stages. The scoring results obtained by three different teaching methods are shown in Table 2.

Table 2. Teaching quality evaluation results of different teaching systems

	Project	The first stage	Second stage	The third phase
Simulation teaching system based on DCS	Rating level	General	Pass	Pass
	Fraction	71	62	61
Simulation teaching system based on fuzzy control	Rating level	Pass	Pass	Good
	Fraction	64	69	80
Simulation teaching system based on MATLAB	Rating level	Excellent	Excellent	Excellent
	Fraction	97	98	98

Observe the results in the table. Among them, the teaching quality score of the DCS-based simulation teaching system in the three stages is between pass and general; the simulation teaching system based on fuzzy control has the teaching quality score of the three stages between pass and good; The simulation teaching system based on MATLAB has excellent teaching quality in the three stages. Because the MATLAB-based simulation teaching system uses MATLAB to establish the mathematical model of the automatic control system, describe the dynamic characteristics of the automatic control system's operation process, and construct the automatic control system curriculum simulation teaching system, which improves the stability of the teaching system. Combined with the results of the consistency reliability experiment, it can be seen that the proposed MATLAB-based automatic control system course simulation teaching system has high teaching quality and high consistency reliability. In the actual automatic control system course teaching, the teaching effect is better.

4 Concluding Remarks

This paper focuses on the research and analysis of the automatic control system course teaching. With the support of the original teaching system materials and literature, a MATLAB-based simulation teaching system design for the automatic control system course is proposed. After the design is completed, it is verified by multiple sets of comparative experiments. The practical performance of the proposed MATLAB-based simulation teaching system solves the problems faced by the simulation teaching of the

automatic control system course at this stage to a certain extent. However, due to the limitation of one's own ability and knowledge, coupled with the fact that the automatic control system course teaching system is a research field involving a wide range and high requirements, there will inevitably be some shortcomings in the research, which will be carried out in the follow-up research. In-depth research and discussion.

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