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Teaching System Identification by Remote Access to a Networked Control System Laboratory*

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Remote experiment courses can expand the boundaries of the classroom, allowing students to conduct experiments anytime and anywhere. This paper takes the system identification experimentation as an example to introduce how to use the remote laboratory to carry out online experiments for system identification. The physical equipment is deployed into the Networked Control System Laboratory (NCSLab) and is used to conduct remote experiments, and the corresponding input/output signal data are collected for parameter identification. The experiment course discussed in this paper combines system identification models, classical identification methods, least squares method, offline identification, online identification, and other theories to provide a thorough experimental design and experimental processes. To validate the effectiveness, the proposed method has been applied to an undergraduate system identification course at Wuhan University. The results show that the remote experiment course has positive application effects and is of great significance to the reform of the existing experimental teaching system.

Keywords: system identification; remote experimentation; least squares method; engineering education in control; experimental design

1. Introduction

The experiment is an important means for students to learn engineering knowledge and consolidate professional abilities. Although conventional engineering laboratories allow students to conduct experiments at their own pace, students also have to follow resource allocation and time constraints. Gathering in conventional laboratories for experiments becomes more challenging, especially under the influence of the COVID-19 pandemic. Consequently, in pursuance of realizing resource sharing and reducing management costs, research on online laboratories has flourished in recent years. At present, online laboratories in science and engineering fields are mainly classified into two categories: remote laboratories and virtual laboratories according to equipment functions [1]. Virtual laboratories can prevent high-risk equipment from harmful consequences caused by novice users [2], while remote laboratories can carry out experiments remotely through network technologies [3]. Users can access remote experimental resources and carry out online experiments on the host computer simply by using a browser or a native application.

Numerous universities and colleges have achieved some success in how to combine remote laboratories with conventional laboratory courses [4–8]. In literature [4], the development, structure, and implementation of a remote laboratory are described by applying formation control of mobile robots and a ball plate system as complementary tools for the teaching of control engineering at the bachelor's and master's levels. In literature [5], the authors carried out experiments related to the robotic system using the remote laboratory named "Sistema de Laboratorios a Distancia", which demonstrates the effectiveness of remote laboratories. Moreover, a remote infrastructure for the education in mechatronics based on cloud services is described in [6] which can reduce the costs associated with traditional laboratories. In literature [7] and [8], the development of the laboratory based on Arduino and the three-tank system are described, respectively.

System identification is to get the mathematical model for determining the behavior of a system by observing the input-output of the system as a function of time [9–11]. It is an important complement to the theoretical courses in automation and a prerequisite for theoretical analysis, as well as an important part of information science and artificial intelligence. Through the learning of the system identification course, students can not only master the basic theory, knowledge, and methods of system identification, and understand the development prospects and application fields of system identification, but can also lay a solid foundation for further in-depth learning of control theory and intelligent control. At present, the design of experimental courses for system identification mainly relies on simulation software such as MATLAB/Simulink and LabVIEW. In the study of [12], the

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particle swarm optimization (PSO) algorithm is used to solve the open-loop identification problem whose purpose is to improve students' skills in the fields of control engineering and computational intelligence. Concha et al. [13] propose a free Android application named Control and Identification Toolbox (CIT) to teach the parameter identification of dynamic systems. However, there are two main limitations to the existing system identification experimentation: firstly, the experimental data is mostly based on simulation software, which is disconnected from the actual industrial application scenarios; and secondly, identification based on physical equipment must be carried out in traditional laboratories, which is difficult to achieve when emergencies make travel difficult, such as the impact of the COVID-19 pandemic.

Therefore, to achieve resource sharing and raise teaching standards, this paper focuses on the theoretical knowledge in the system identification course, combined with the remote experiment with physical equipment in the NCSLab, starting from the basic theory such as the two-point method, least squares and online identification methods, allowing students to carry out experimental operations such as algorithm design, data acquisition, and data analysis through the remote laboratory to consolidate the theoretical knowledge in practice. The experimental results prove that it is realistic and feasible to conduct system identification experiments based on the NCSLab, which is of great significance for reforming the existing system identification experimental teaching system in engineering.

The paper is organized as follows: Section 2 introduces the architecture and main functionalities of the NCSLab. The experimental arrangement is discussed in Section 3. The realization process and content of system identification remote experimentation and an example of a system identification experiment are introduced in Section 4. Section 5 analyzes the questionnaire survey of undergraduate students' satisfaction with the system identification remote experimentation. The experimentation result is discussed in Section 6. Finally, concluding remarks are discussed in Section 7.

2. The Remote Laboratory – NCSLab

NCSLab [14, 15] is a remote and virtual laboratory based on automation-related courses. It is equipped with six kinds of physical equipment and more than 20 sets of virtual equipment for students' remote experiments. The platform is based on a browser/server (B/S) architecture, which allows users to access the experimental platform via https: //www.powersim.whu.edu.cn/react without the need to install plug-ins or client applications.

2.1 Laboratory Architecture

NCSLab has been iterated over the years to form a four-layer laboratory architecture containing a front-end user interface – a central server cluster – regional servers – and experimental equipment, as shown in Fig. 1.

The front-end user interface is mainly based on React.js framework, providing a graphic user interface for interacting with the user. The interface can transmit real-time data and video streams with the back-end server to meet the needs of users to conduct real-time experiments on the front end.

The central server cluster is the core part of the entire system, and HTTP requests are uniformly forwarded by the NGINX proxy server. The cluster includes a PHP server that provides application programming interfaces, a file server that stores front-end JavaScript code, an MYSQL server to interact with the database, and a MATLAB server for compilation and simulation of control algorithms.

The experimental equipment is the object on which the actual experimental control is carried out. Once the user starts experimenting with front-end user interface, the video server transmits the real-time video streams showing the real-time operation of physical equipment.

2.2 Main Functionalities of NCSLab

To meet the experimental needs of different users, the following main functionalities have been developed in the NCSLab:

(1) Independent online algorithm design module.

The remote laboratory generally offers fixed control algorithms in most cases, which limits the autonomy of users. To meet the various needs of users, NCSLab not only provides default algorithms designed by the teacher, such as classic PID control, open-loop control, and steady-state error analysis, etc., but also provides an online algorithm design module that allows users to design their control algorithms. The front-end interface of the module offers visual graphics to build algorithms, which reduces the user's requirements for experiments, for example, without programming skills, and allows users to focus on the experimental process [16]. At the same time, the S-function module is also provided in the online algorithm design module to allow users to design private control algorithms, which can be compiled into an executable program in conjunction with the back-end Simulink Coder and downloaded to the

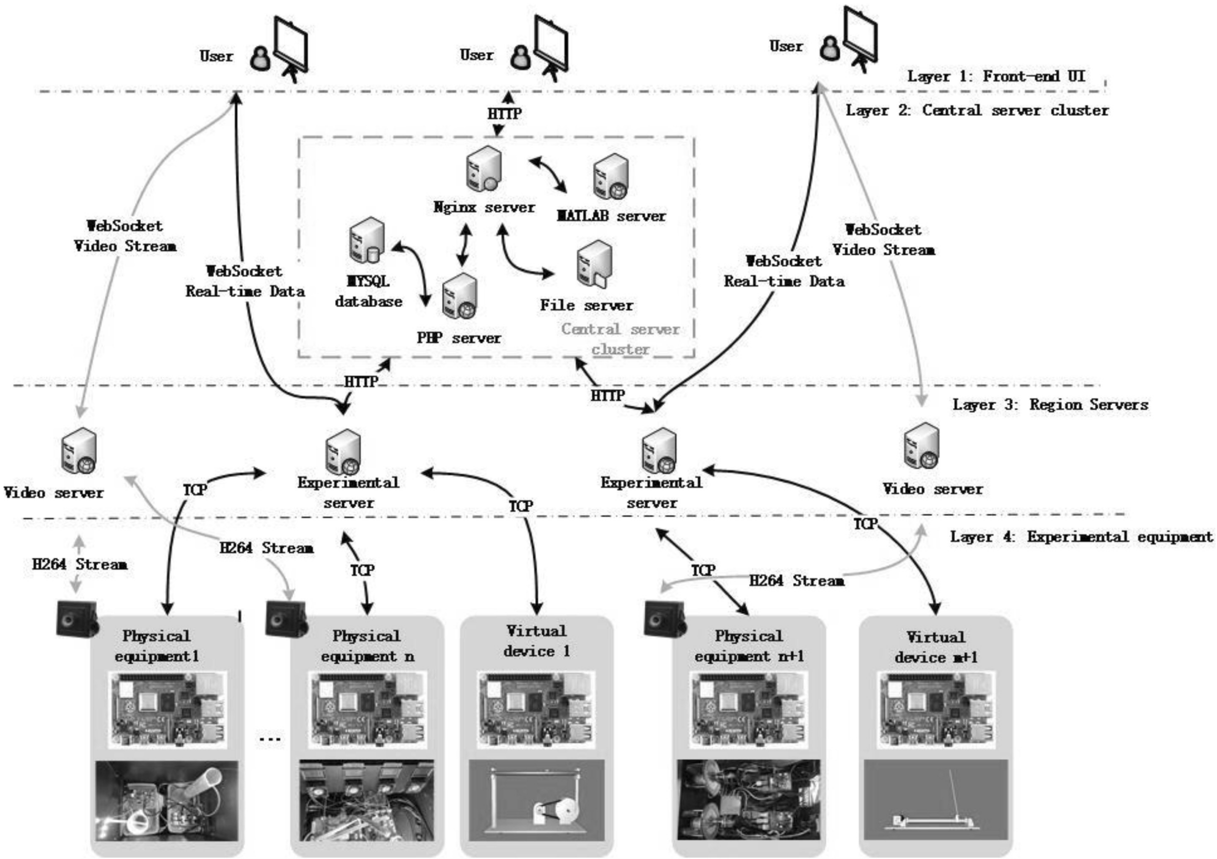

Fig. 1. Laboratory Architecture.

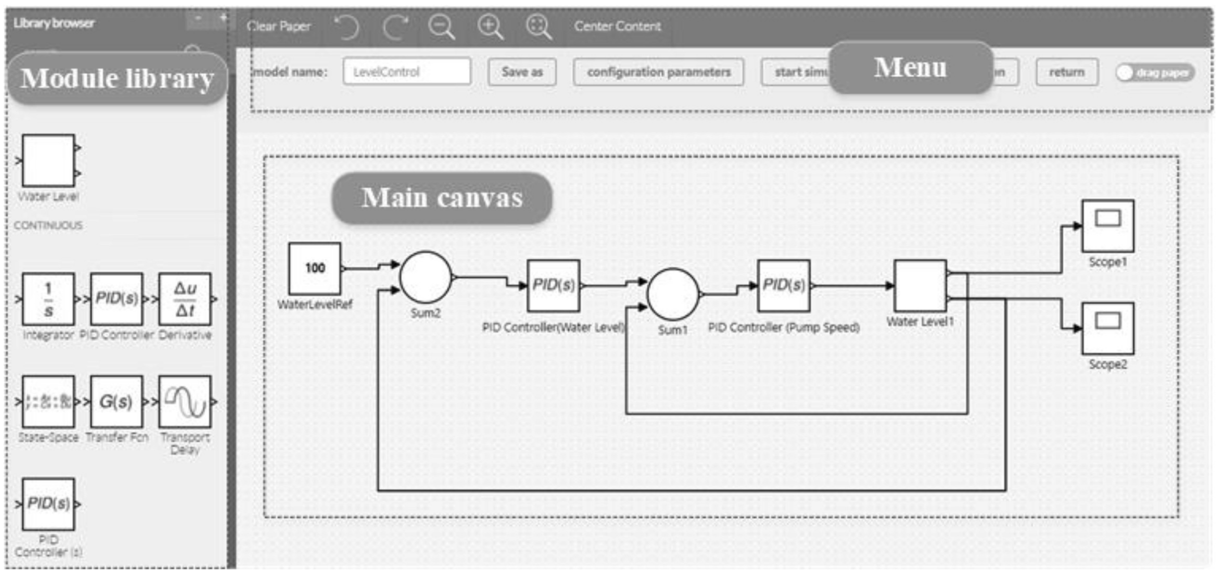

Fig. 2. Online algorithm design interface.

remote controller for experiments in the NCSLab. A great deal of freedom is given to users by the online algorithm design module, which allows a wide range of experimental operations to be carried out using physical equipment. Fig. 2 shows the online algorithm interface of the double closed-loop control algorithm of the single tank water level control system. The interface is divided into three parts: the module library, the menu bar, and the main canvas, where the user can drag and drop modules to compose control block diagrams, followed by simulations and real-time experiments.

(2) Virtual and real experiment experience.

NCSLab not only provides virtual equipment for users to conduct experiments, such as fans, inverted pendulums, combustion process control systems, etc., but also offers physical equipment, such as DC motors, single tanks, and fans. For each of the physical equipment, the corresponding 3D visualization models have been developed. For novice users, simulation experiments can be performed on virtual equipment, and the experimental data are obtained by simulation software. The results are ideal and easy to analyze. While advanced users can choose the corresponding physical equipment to conduct experiments where interference factors such as system input and output limits and system model errors will be considered, which is more challenging.

(3) User experimental operation evaluation system.

In the NCSLab, users are classified into four categories – administrator, teacher, student, and visitor – to facilitate the management of users' experimental behavior. The administrator can set up the experiment guide, assign an experimental task list, and experiment algorithms of the corresponding course on the platform. Following the experimental instructions, and combined with the task list, students can complete the experimental operations during which the system records the completion of the students' experimental operations. The teacher can view the completion of the students' experiments on the teacher management interface, and then combine it with the students' experimental reports to generate scores for the experimental course.

3. Experiment Procedure

The remote experimentation in the System Identification course is combined with the NCSLab to provide students with the theoretical knowledge of linear time-invariant systems, simulation and prediction, parameter estimation, offline identification, and online identification, allowing them to conduct remote physical experiments through the Internet to improve their practical hands-on skills and deepen their understanding of system identification theory.

3.1 Remote Experiment Design

The basic steps of the system identification experimentation can be summarized as the following steps: (1) Choose the excitation signal and design the identification algorithm; (2) Conduct experiments to obtain input and output data; (3) Determine the structural model of the observation system; (4) Carry out parameter identification for the known model structure; (5) Check whether the identified model meets the expected requirements. As shown in Fig. 3.

The design ideas of the system identification remote experiment course can be concluded as follows:

(1) Building algorithm. Using the online algorithm design module of the NCSLab, the identification algorithm can be built online. This module provides a graphical approach to system simulation and modeling, which is convenient for students to master. After the algorithm is built successfully, an executable program can be generated and downloaded to the remote controller.
(2) Experimenting. Traditional system identification experiments use special embedded development tools for experimental control, data acquisition, and other operations, requiring professional programming knowledge and making it challenging to get started. NCSLab can directly conduct experiments after downloading the algorithm. The monitoring configuration interface it provides can observe the operation of remote physical equipment in real-time and can adjust parameters in real-time to obtain ideal input and output signals.
(3) Collect data. According to different experimental contents, input and output signals are collected and corresponding data preprocessing is performed, for example, random two-point data are collected in the two-point identification of the step response method; input and

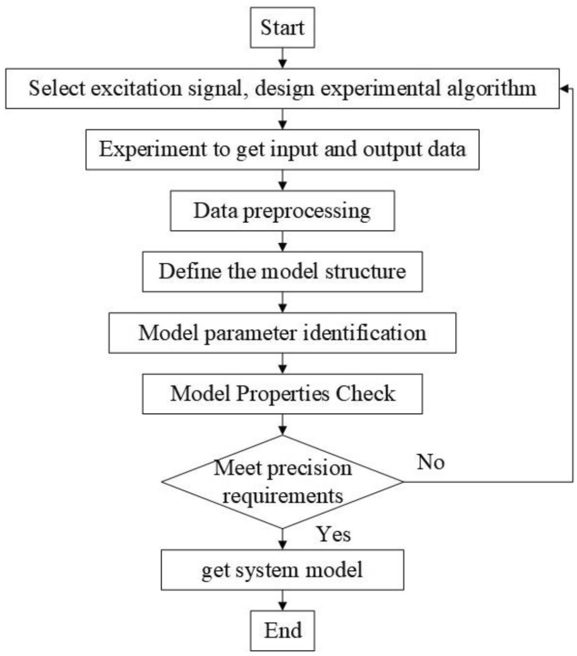

Fig. 3. System identification experiment process.

Table 1. System Identification Remote Experiment Course Arrangement

Experimental content	Knowledge points of inspection	Equipment	Percentage of marks
Two-point method identification based on DC motor	Mathematical model analysis of motor and two-point identification method in step response method	DC Motor	25%
Fan-Based Least-Squares Identification	Basic principles of least squares identification algorithm and the writing of MATLAB algorithms	Fan	25%
Motor-based online identification	Construction of online identification algorithm for first-order observation system	DC Motor	25%
Comprehensive experiment	Ability to independently design system identification algorithms	Water tank, floatation, motor angle system	25%

Note: The algorithm of the comprehensive experiment is user-designed.

output data sets are collected in the offline identification of the least-squares method; collecting input and output data of online identification and physical equipment in online identification experiment.

(4) Define the model structure. The remote experimental equipment required for system identification includes motor speed control systems, fan speed control systems, and single tank level control systems. They are the basic component of the industrial system and the mathematical model is of low order, so it is easy to carry out theoretical analysis to obtain the structural model, which is convenient for students to understand and control. For a specific observation system, the structural model can be obtained after theoretical analysis.

(5) Parameter identification. After the input and output data and model structure are obtained, different parameter identification processes are carried out according to the experimental content. For example, in the identification of the two-point method, the two-point data is directly brought in; in the offline identification of the least square method, the data is imported into MATLAB for identification; in the online identification experiment, the identification process has been completed during the experiment.

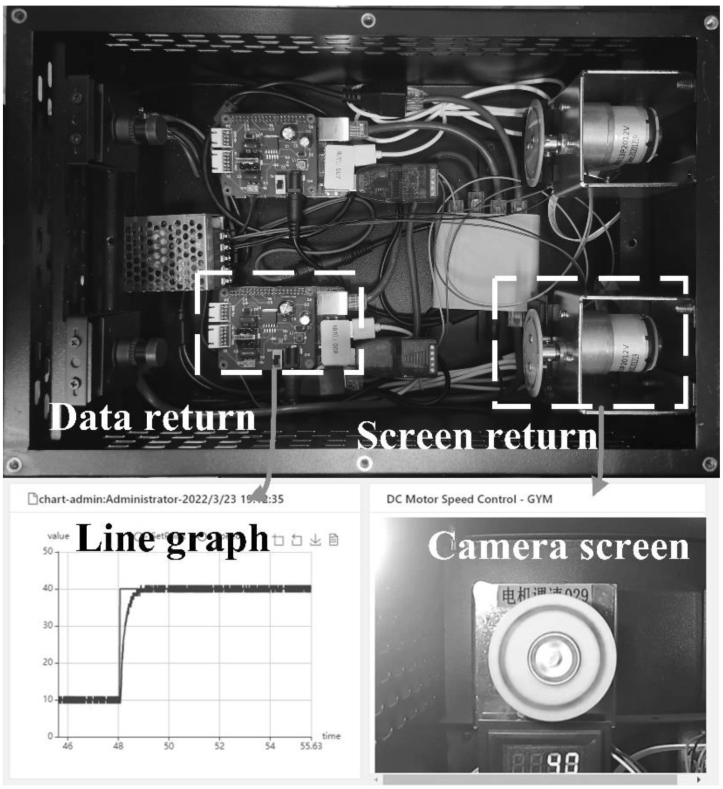

Fig. 4. Motor Speed Control System Experiment Box.

(6) Accuracy calibration. Since the system identification course is applied to the teaching of theoretical knowledge, focusing on cultivating students to establish the system identification process and master the basic identification methods, it is only necessary to verify whether the operation conditions of the identification model and the actual equipment are consistent.

3.2 Remote Experiment Content

The course covers the application of identification theory, linear time-invariant systems, selection of excitation signal, two-point identification in step response method, least-squares identification algorithm, and recursive least squares identification algorithm in offline identification, online identification algorithm, neural network identification, and other theoretical knowledge. Therefore, two-point identification, least-squares identification, and online identification are selected as the experimental contents and the specific experimental arrangement is shown in Table 1.

Next, the specific remote experimental process is described using the online identification of the DC motor as an example. The physical equipment of the motor speed control system is placed in the laboratory of the National Virtual Simulation Experiment Teaching Center of Wuhan University and has been connected to the NCSLab, which is open to users 24 hours a day. The system integrates the motor, controller, encoder, camera, and other devices to complete the monitoring and data acquisition of the motor, as shown in Fig. 4.

According to the theoretical analysis of the DC motor, the system can be approximated as a first-order inertial system, and its ARM model is shown in Equation (1):

$$y(t) = \theta^T \varphi(t) = -a_1 y(t-1) + b_1 u(t-1) \tag{1}$$

where $u(t)$, $y(t)$ are the input and output of the motor, and a_1, b_1 are the constant parameters.

The basic idea of the recursive least squares method is that based on the estimated value $\hat{\theta}_{t-1}$ of the model parameters at the previous moment, the data at the current moment is used to correct the estimated value $\hat{\theta}_{t-1}$ at the previous moment, to obtain the estimated value $\hat{\theta}_t$ at the current moment. Compared to the least-squares batch algorithm, the recursive algorithm is less computationally intensive, more real-time, and more suitable for online real-time computer identification. Equation (2) is the iterative formula of the widely used recursive algorithm:

$$\begin{cases} \hat{\theta}(t) = \hat{\theta}(t-1) + L(t)\left[y(t) - \varphi^T(t)\hat{\theta}(t-1)\right] \\ L(t) = \dfrac{P(t-1)\varphi(t)}{\lambda(t) + \varphi^T(t)P(t-1)\varphi(t)} \\ P(t) = \dfrac{1}{\lambda(t)}\left[P(t-1) - \dfrac{P(t-1)\varphi(t)\varphi^T(t)P(t-1)}{\lambda(t)+\varphi^T(t)P(t-1)\varphi(t)}\right] \end{cases} \tag{2}$$

where $\lambda(t)$ is the forgetting factor, $R(t) = \sum_{k=1}^{t} \varphi(t)$, $P(t) = R^{-1}(t)$. To facilitate students' under-

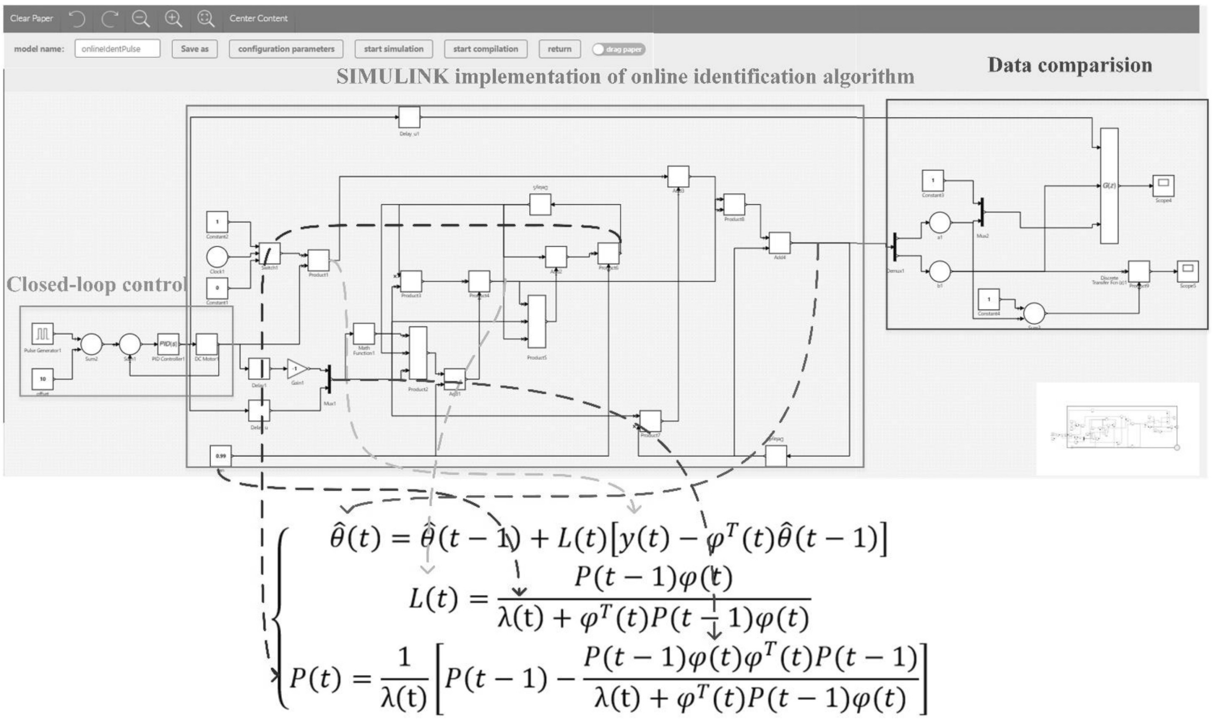

Fig. 5. Online Identification Algorithm Built by Online Algorithm Module.

standing and construction of the algorithm, the algorithm is transformed into a control block diagram, which is designed through the online algorithm design module of the NCSLab, as shown in Fig. 5. Students can also design s-function modules for experiments.

The algorithm selects the pulse signal as input and collects the motor control volume and actual speed from the motor closed-loop control algorithm as the online identification data, and updates the parameter estimation value in each sampling interval, to achieve the purpose of real-time identification.

After the remote control algorithm is generated, the user can monitor the operation of the online identification algorithm on the motor system in real-time on the platform, and obtain real-time parameter identification results. Fig. 6 is a graph of the real-time operation of the real motor and the online identification and simulation results. The first-order ARX model of the motor at this moment can be obtained as Equation (3):

$$y(t) = 0.84y(t-1) + 7.56u(t-1) \qquad (3)$$

As can be seen from Fig. 6, the simulation output of the online identification model has a good degree of fitting with the real-time motor speed curve, indicating the reasonableness and effectiveness of using a first-order ARX model to describe a motor speed control system. Students can also adjust the value of the forgetting factor in real time to test the impact of the change of this parameter on the real-time identification process.

4. Experiment Arrangement

4.1 Experiment Assessment Content

The experimental assessment includes three parts: experimental operation, data analysis, and the experimental report. The specific assessment requirements are shown in Table 2.

In the course of the remote experiment, NCSLab will record and analyze the operation steps of students on the platform in the background. Students are required to complete their experiments individually to receive the corresponding operating marks. During the experimental operation, students not only need to learn the construction of

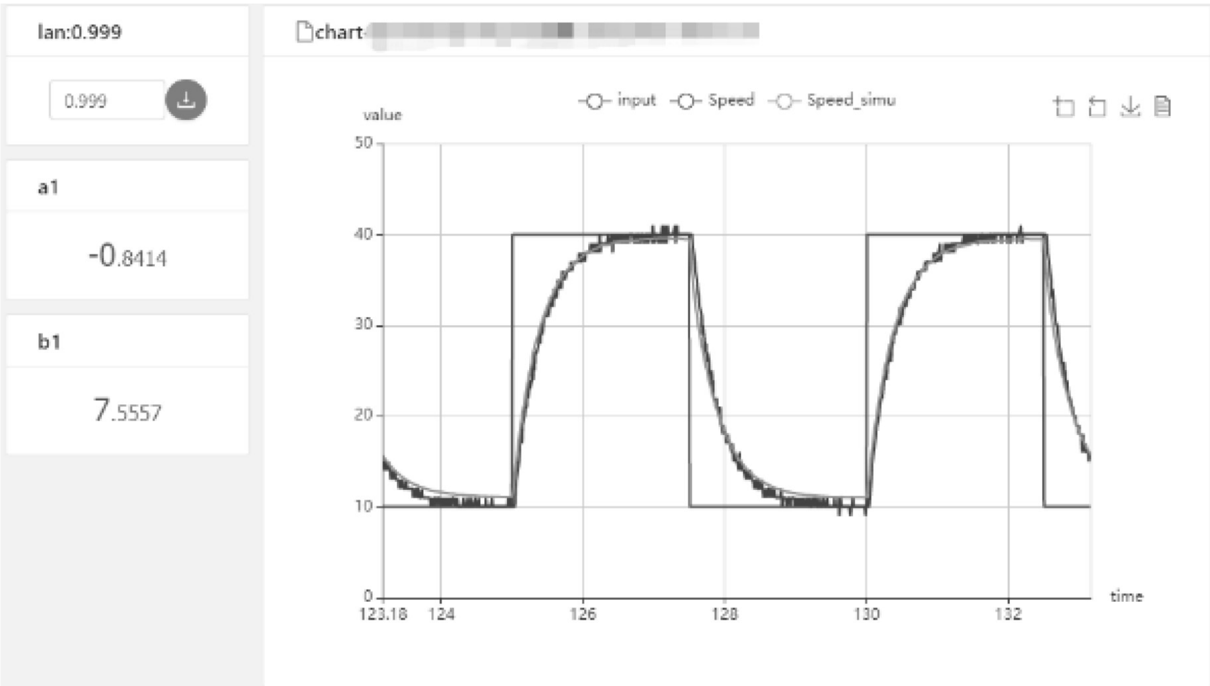

Fig. 6. Online identification and verification curve of the motor.

Table 2. System Identification Experiment Assessment Requirements

Exam topic	Examination content	Fraction scale
Experimental operation	Familiar with the operation steps of the remote laboratory. Understand and master how to build identification algorithms	40%
Data analysis	Learn how to use the two-point method and least-squares method for identification, and calculate the matching degree of identification results	40%
Experimental report	Master the complete identification process and the ability to summarize in writing	20%

the identification algorithm but also need to learn the process and method of using the NCSLab.

The data analysis process varies slightly depending on the content of the experiment, but students should reflect on it in detail in the experimental report. In the system identification experiment, the process needs to record the detailed process of how to identify the parameters through the input and output data, rather than simply recording and calculating the data. The system model obtained by data analysis needs to have a high degree of fitting with the actual equipment.

After the experiment is completed, students need to further improve by writing an experimental report. For online experiments, we have designed a dedicated experimental report template. The experimental report should reflect the experimental purpose, experimental principle, online experimental steps (with screenshots of the experimental process), experimental analysis, experimental results (with screenshots of the experimental process), and the problems and solutions encountered in the experiment. The writing of the experimental report will help students sort out the experimental process, summarize the integration of experimental and theoretical knowledge, as well as reflect on the problems encountered in the experimental process, and answer the thinking questions based on the theoretical knowledge in the experiment, to deepen impressions of knowledge.

Finally, combined with the three parts of the experimental operation, data analysis, and the completion of the experimental report, the final grade of the experimental course is obtained.

4.2 Experimental Course Arrangement

The remote experiments of the system identification course rely on the NCSLab, which has been implemented in the relevant courses of the automation major of Wuhan University since 2011 and has been open for many years. After continuous iterations, combined with the latest experimental equipment, the remote system identification experiment is piloted in the system identification course for the automation students of the class of 2016 and 2018 (the first semester of 2019, 2021), and the specific course arrangement is as follows: the system identification course is open to the automation students of the class of 2018, and the nature of the course is a professional elective course, with a total of 24 credit hours and 1.5 credits. It mainly involves knowledge points such as linear time-invariant systems, the application of the least-squares method, offline identification, and online identification. The physical equipment applied to it is deployed and applied in the NCSLab.

The remote experiment implementation of the system identification course is mainly divided into four steps. (1) the teacher arranges and distributes the courseware and experimental content to the students before the course, and the students conduct an independent preview; (2) after the teacher explains the theoretical knowledge points in class, the teacher will demonstrate the experimental process in the classroom according to the content of the courseware, and explain the experimental steps step by step; (3) the students carry out the experiments independently according to the experimental guide and the process explained by the teacher, and the teacher can observe the students' experimental status and provide relevant guidance at any time; (4) after the course is over, students who have not completed the experiment independently decide the time and place to conduct the experiment and submit the experimental report before the deadline.

5. Evaluation

Since 2015, NCSLab has been applied to classroom demonstrations and laboratory courses in system identification and has been well received. The final grade for the course is determined by a combination of laboratory performance and examination results, each accounting for 50 percent. The difficulty of the examinations is also maintained at the same level in all years. The final results of the system identification course since 2013 were collected for analysis. As seen in Table 3, the grades can be divided into two main categories, without remote experiments applied to NCSLab from 2013–2014 and with remote experiments applied from 2015–2021. Although the number of students taking the course has been gradually increasing in recent years, the average course grade has risen from 81.78 to 83.75 after the assisted remote experiments, thus demonstrating the effectiveness of the proposed teaching model in improving student learning skills.

The questionnaires are designed for the stability of the experimental platform, the fluency of experimental operation, and the design of experimental courses, including multiple-choice questions which are shown in Table 4. The feedback from students using this remote control laboratory for system identification experiments was tallied and analyzed. After compiling data from two years (2019, 2021) of this system identification course, a total of 60 user questionnaires were received. The multiple-choice

Table 3. Changes in student performance

Years	Number of Students Selected	Average Grade
2013–2014	156	81.78
2015–2021	412	83.75

Table 4. Multiple choice questions to analyze the student satisfaction toward the NCSLab

Questions	CD	D	I	A	CA
Q1: Do you think the NCSLab system is easy to operate?	–	–	2	24	34
Q2: Do you find the experiments on NCSLab smooth?	2	2	5	29	22
Q3: Do you find it stable to conduct experiments on the NCSLab?	2	2	6	31	19
Q4: Do you think the online algorithm design function of the NCSLab system is easy to operate?	–	1	3	34	22
Q5: Do you find the ability to do algorithm design directly in the NCSLab convenient?	–	–	8	31	21
Q6: Do you think the response speed of online algorithm design is fast?	–	2	3	41	14
Q7: Do you think online algorithm design has helped you create a more intuitive impression of the experimental content?	–	–	10	27	23
Q8: Do you think the equipment monitoring audio and video provided by the NCSLab can help the cognition of the control process?	–	–	–	11	49

questions give five options at different levels – completely disagree(CD), disagree(D), indifferent(I), agree(A), and completely agree(CA). Table 4 shows the answer results of these multiple-choice questions. It can be seen that the students are satisfied with the application of the NCSLab for remote system identification experiments, because most of the answers are agree(A) or completely agree(CA). 86.67% of the students believed that the remote experiment could stimulate their interest in the course. The web-based laboratory of the NCSLab based on the B/S architecture allows students to avoid downloading the client program on the host computer, and the experimental method of entering directly from the browser is more convenient and faster. All the students believed that the application of monitoring modules such as graphs and cameras facilitates the understanding of the experimental process. The online algorithm design module set up in the remote laboratory eliminates the need to jump between multiple platforms, which is positive for simplifying the experimental process.

These students also answered questions about the teaching significance of the remote laboratory, as shown in Table 5. Through this experiment, we can obtain the opinions of the students participating in the experimental design on the remote experiment. The options for multiple-choice questions are the same as that in Table 4. It can be seen from Table 5 that students have a positive attitude towards conducting remote experiments, and believe that remote experiments can deepen their understanding of the theoretical knowledge of system identification. In addition, the students who participated in the experiment believed that compared with the traditional system identification simulation experiment, the identification experiment based on remote equipment could deepen the understanding of system identification.

In addition, some quizzes with comments on the NCSLab are filled out for improvement and future

Table 5. Students' Perspectives on Remote Experiments

Questions	CD	D	I	A	CA
Q1: Do you feel that conducting remote/virtual experiments can stimulate your interest in learning?	–	1	7	37	15
Q2: Do you find conducting remote/virtual labs helpful for your course?	–	–	–	38	22
Q3: Do you feel it is necessary to conduct remote/virtual experiments?	–	4	7	40	9
Q4: Do you find conducting remote experiments helpful for your understanding of experiments?	–	–	4	39	17

Table 6. Students' Perspectives on Remote Experiments

Questions	Feedback Answer
Q1: What other physical devices do you think can be added to the NCSLab?	1. Steering gear 2. Brushless motor 3. Robotic arm 4. Drum water level 5. Power electronics experiment
Q2: What new features do you think the NCSLab could add?	1. Exchange forum 2. New modules in algorithm design
Q3: What problems did you encounter while using the NCSLab?	1. Sometimes the page crashes and needs to be re-entered 2. When the network is unstable, it will affect the use of the web page 3. Can't load task list

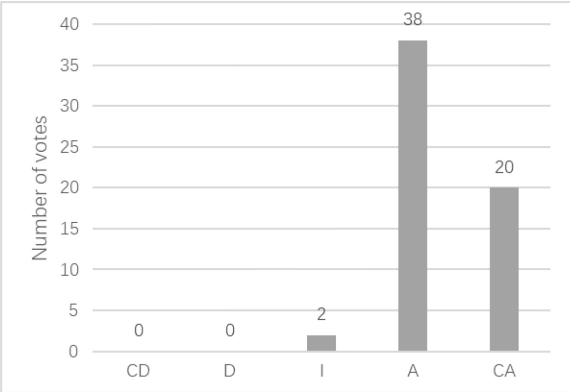

Fig. 7. Overall user experience satisfaction.

development of the laboratory, as shown in Table 6. For the future development of the NCSLab, students hope to add physical experimental equipment such as servos, robotic arms, and brushless motors to the platform. For personal experimental experience, students hope to add functions such as communication forums to the NCSLab, and also hope to add new modules in the algorithm design module. When asked what unpleasant experiences they encountered during the experiment, some students responded that when the network connection is unstable, the experiment process will become stuttered. Finally, they believe that the remote system identification experiment is generally satisfactory, and the remote experiment method can be extended to other engineering experimental teaching, as shown in Fig. 7.

6. Discussion

The result of this course experimentation, which is an optional course in the fourth academic year of the Automation major, shows that the course is advantageous from an educational and applied point of view. To complete the experimental course, students need to carry out theoretical analyses for different experimental equipment and apply identification algorithms from simple to difficult. In the comprehensive experiment, students develop engineering skills by designing their experiments, example include theoretical analysis for experimental equipment, designing control algorithms, collecting experimental data using the remote laboratory, and data processing using simulation software.

From the point of view of the student, firstly, the primary functionalities of the NCSLab, such as algorithm design, configuration monitoring, data acquisition, etc., meet the basic requirements of students for physical experiments and allow them to carry out a variety of experiments on the platform, including system identification experimentation. Secondly, the previous system identification experimentation was mostly conducted using simulation software. Using the remote experiment platform to conduct physical experiments can bring a more realistic and tangible experimental experience.

Compared to LabView, the NCSLAB is equipped with a wide range of experimental equipment, both physical and virtual, and provides a window for monitoring and configuring the equipment in real-time. In addition, NCSLab is equipped with user management and personalized task lists, allowing teachers to keep track of students' progress. The easy-to-follow procedure focuses students' attention on the experiments and analysis.

However, there are still areas where the lab is lacking, such as the lack of more complex laboratory equipment, and the lack of a discussion forum for collaborative learning, which still needs improvement but does not affect the current basic functionality. Overall, from the evaluation, the use of the remote laboratory for system identification experimentation is satisfactory for students and the mode of experimentation can be applied to other engineering courses in the long term.

7. Conclusion

Based on the physical equipment in the NCSLab and the theoretical knowledge in the system identification course, this paper designs remote experimentation for the system identification course. The experimentation covers the step response method, least squares method, and online identification method in the identification theory, and sets up the experimental assessment criteria. The remote experimentation in the system identification course has proved to be of great importance in consolidating students' basic theoretical knowledge and enhancing their interest in learning in the theory courses of students of the Automation major. At the same time, using the remote experimental platform of the NCSLab, more remote experimental courses can be designed based on 3D virtual and physical experimental equipment, which can also be applied to engineering experimental teaching.

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