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A study of multi-objective dynamic planning for intelligent laboratory management programs in nonlinear engineering environments

Zhaoyuan Zhang[1,✉]

[1] *Mechanical Engineering College, Xi'an Shiyou University, Xi'an, Shaanxi, 710000, China*

ABSTRACT
The expansion of information-based education and the growing need for computer laboratories have made their day-to-day management a key part of teaching and learning management activities. The traditional manual management method is inefficient and difficult to handle the increasingly complex management tasks. The emergence of optimized management systems has effectively improved the effectiveness and quality of computer laboratory management work, but the operational efficiency and security of management systems are also facing enormous challenges. To improve the real-time and security of management systems while efficiently completing management tasks, this paper conducted in-depth research on the design of computer laboratory optimization systems using nonlinear engineering algorithms. To verify its effectiveness, this article tested the system from three perspectives: functional implementation, running load, and security performance. The experimental results showed that at the functional implementation level, the average response time of the system for each test case requirement was 1.0767 seconds. It can be seen from the specific results that the demand response speed of the computer laboratory optimization management system based on nonlinear engineering is fast, which can efficiently handle the daily management tasks of the laboratory and promote the improvement of the quality and level of teaching management.

Keywords: Computer Laboratory Management, Nonlinear Engineering, Teaching Management, System Design

1. Introduction

With the increasing experimental needs of researchers, traditional laboratories may impose certain constraints on experimental work, and the problems of lagging relevant information and relatively low management efficiency have arisen [1-2]. For example, when the number of people in the

✉ Corresponding author.
E-mail address: zyzhang@xsyu.edu.cn (Z. Zhang).
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laboratory reaches or exceeds the controllable threshold, the laboratory managers will lose sight of the situation, and it is difficult to achieve the effect of management. It also includes problems such as chaotic laboratory management, random entry and exit of staff, and damage, loss, and lack of experimental instruments. Internet of Things (IoT) technology is a reasonable choice to solve these problems, and intelligent devices of IoT can be used to replace certain traditional devices, and the subsystem devices can be easily interconnected with each other [3-4]. When laboratory management is automated, all aspects of management will be precise, which not only reduces manpower but also saves resources [5].

With the emergence of the Internet of Things (IoT) technology, the need to establish a scientific and accurate management system has become more and more prominent. IoT connects hardware facilities to the Internet, realizing the "Internet of Everything", breaking the barrier between physical hardware and information systems, providing new perspectives for laboratory management and use, and advancing the development of smart laboratory systems [6-9]. Intelligent laboratory systems are based on IoT technology to reduce management costs, improve the efficiency of laboratory management and use, and increase the practice opportunities for staff [10-11]. In addition, the traditional laboratory management system focuses on the bottom layer of IoT, the system is relatively simple and single function, which has some limitations in laboratory management [12-14]. On the other hand, the smart laboratory system is the intelligence of laboratory management system, which works throughout the whole IoT with complex and fine features [15-17]. Through rich data acquisition sensors and controllers, powerful and complex logic processing ability, it realizes rich functions, improves the intelligence and informatization of laboratory management system, and promotes the opening of laboratory [18-19].

To address the current high demand for computer laboratory management and low efficiency of daily management work, this article combined nonlinear engineering to effectively study the design of a computer laboratory optimization management system. To verify its application effect, this paper tested it from three aspects: function implementation test, running load testing and security performance test. With the support of nonlinear engineering algorithms, the system has higher efficiency in management work and task analysis, and faster response time. Compared with traditional computer laboratory management systems, this system has stronger security performance and can effectively adapt to different operating environments, providing strong support for teaching and laboratory daily management work. In practical applications, computer laboratory optimization management systems based on nonlinear engineering can effectively assist in management work and promote the intelligent development of information education.

2. Design of Computer Laboratory Optimization Management System

2.1. Requirement Analysis

2.1.1. Functional Requirements. In the information age, the development of intelligent learning environments has promoted the development and use of computer laboratories. Currently, many schools face enormous challenges in laboratory management. The computer laboratory management system is an intelligent platform that combines information management concepts with high-speed data processing technology based on computer networks, and unifies the management of the laboratory and its daily teaching work. It provides great convenience for educators, learners, and managers. In order to effectively assist teachers, students, and laboratory managers in teaching, learning, and management in practical applications, its design and construction must determine its functional requirements from the perspective of users.

In the process of teaching management, for teacher users, the system needs to assist teachers in completing main tasks such as course scheduling, scheduling, and laboratory appointments. In addition, the computer laboratory management system also needs to use teaching data and information to analyze students' learning status and level, in order to help teachers better complete personalized teaching work. For student users, the system needs to provide them with functions such as course recommendation queries, learning interactions, and classroom records, which can help them better complete learning tasks and gain a better understanding of their learning status.

Schools need to ensure the reasonable allocation of laboratory teaching resources, so that experimental teaching work can be carried out more efficiently. In the laboratory management system, laboratory administrators need to use the system to effectively manage equipment. At the same time, laboratory administrators also need to utilize the system to achieve information management, including database management, in order to ensure the safety and stable operation of the laboratory.

2.1.2. Performance Requirements. The performance requirements for computer laboratory optimization management system include five aspects:

1) Security. Due to the abundance and variety of laboratory equipment and information, scientific daily management requires high levels of safety. Each computer laboratory would be open to society in its spare time to improve its efficiency and provide students with a high-quality learning environment. Therefore, when designing a computer laboratory optimization management system, security issues need to be taken into account.

2) Real time. In the computer laboratory management system, administrators manage the computer laboratory through network communication and remote control. The most fundamental performance requirement of this remote control digital system based on communication networks is to meet the needs of digital resource sharing. It emphasizes the real-time nature of information transmission. In the process of resource scheduling or data transmission in the system, there may be interference from environmental factors, resulting in significant delays and certain delay uncertainties. Therefore, real-time performance is also an essential factor that cannot be ignored in system design.

3) Developmental. The main purpose of constructing an optimized management system is to achieve virtual computing of teaching resources such as laboratories, as well as effective integration and scheduling. In order to complete management tasks more efficiently, it is necessary to comprehensively consider nonlinear factors and establish a nonlinear, horizontal or vertical system service integration. As a part of teaching management work, optimizing the management system requires high openness, in order to continuously expand the system's functions and services, and achieve efficient data transmission and effective coordination of work among various departments in teaching management.

4)Reliability. In the case of highly integrated systems and services, once a system failure occurs, it would have a significant impact on the normal operation of the computer laboratory. Therefore, in the operation process, optimizing the management system must have good reliability. In practical applications, the reliability of computer laboratory optimization management systems also includes the stability of the system during upgrades, maintenance, expansion, and other processes.

5) Operability. The operability of the computer laboratory optimization management system is mainly reflected in its interface design and functional design. Due to its user base including teachers, students, and corresponding management personnel, its interface design and functional design need to be concise and convenient in operation, in order to facilitate users to operate and use according to their own needs.

2.2.Nonlinear Engineering

In practical life, there are various nonlinear effects, whether under natural or non natural conditions. In terms of daily management of computer laboratories, factors such as nonlinear control strategies in control systems are the reasons for the occurrence of nonlinearity in the system. In real life, people usually use linear system as a simple modeling method. Under certain circumstances, it can really simulate and predict the working state of the system. However, these Linear approximation are not completely reliable, and some neglected nonlinear factors may bring unacceptable errors to system analysis and calculation.

In information technology education, it is often difficult to carry out practical teaching in a practical environment. Part of the reason is that the experimental conditions are too harsh to complete, while another part is that the daily management time and labor costs are too high. In education and teaching, facing this situation, computer laboratory optimization management systems are usually used to solve it. However, in the daily management of laboratories, some nonlinear factors are often involved. Therefore, in order to implement optimal management, the ideas and algorithms of nonlinear engineering must be applied.

To facilitate the observation of the impact of changes in management system parameters on periodic response, the estimation function that can provide periodic solutions, and the analysis of daily management work and tasks in computer laboratories, it is assumed that there is a three-dimensional computer laboratory optimization management system:

$$S_1 = f_1(x_1, \cdots, x_n), \cdots, S_n = f_n(x_1, \cdots, x_n) \tag{1}$$

It is assumed that the solution of the system is a curve in the n-dimensional space $d(x_1, \cdots, x_n)$, and $\sum$ is an $n-1$-dimensional subspace plane in d. The describing formula is:

$$k(x_1, \cdots, x_n) = 0 \tag{2}$$

It is assumed that Formula (2) can be simplified as:

$$x_n - i = 0 \tag{3}$$

Since x_n is a parameter of time t in the system formula, it is impossible to directly determine the specific position of $\sum$ in an integration step in the process of numerical integration with time t as the independent variable. However, if x_n can be used as the independent variable and time t as the parameter variable of x_n, the position of $\sum$ relative to the last integration node can be determined, that is:

$$\Delta x_n = -k = -(x_n - i) \tag{4}$$

Correspondingly, the system formula becomes:

$$S_1 = \frac{f_1}{f_n}, \cdots, S_{n-1} = \frac{f_{n-1}}{f_n} \tag{5}$$

In the actual optimization management system programming calculation, the specific approach is to first conduct numerical integration on the original formula until the sign of $k = x_n - i$ changes, and then conduct a one-step integration calculation on the system formula. The initial value is selected from either of the two integration nodes in the last step of integration, and the integration step is set to Δx_n to accurately integrate to the boundary $\sum$. After obtaining the state quantities of the system on the boundary, the integration is continued by returning to the original equations. This can provide a starting point for the management system from a certain initial value. The response process of the management system throughout the entire time domain includes not only the stable state change process of the management system, but also the instantaneous change process of the management system and the operation process of the system that cannot reach a stable state.

2.3.System Construction

According to the concept of nonlinear engineering algorithms, the overall architecture of the computer laboratory optimization management system is shown in Figure 1.

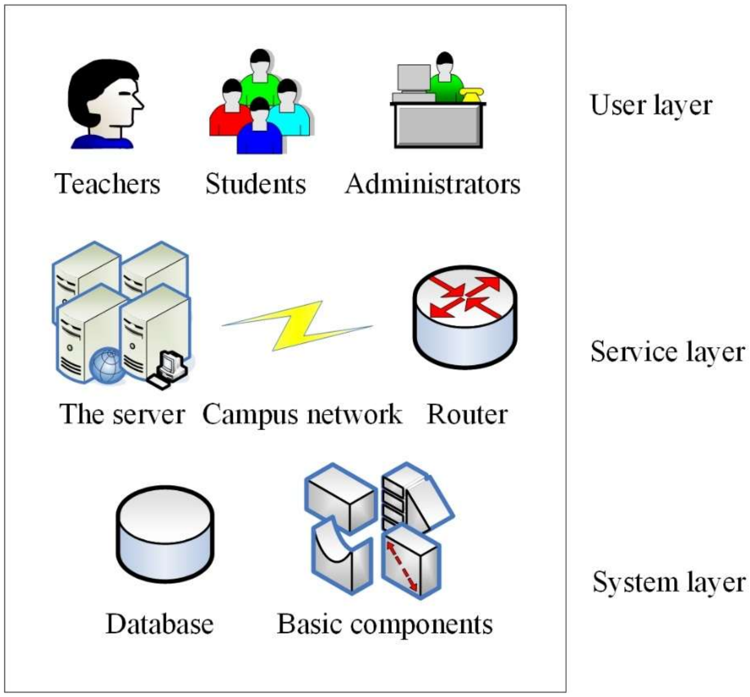

Fig. 1. Overall architecture of the management system

The overall architecture of the laboratory management system is structured in three layers: user layer, service layer, and system layer. This system is designed for computer practical teaching management, experimental equipment management, and information management. Therefore, the functions implemented by the user layer mainly target three types of users: teachers (educators), students (learners), and corresponding management personnel. Three types of users are set in the system, and the user category is the only symbol of usage permission and the main basis for users to have corresponding usage functions. The user's usage functions mainly include:

1) Teachers: Teachers play an important role in the computer laboratory optimization management system, and their main permissions include course arrangement, adjustment, student information query, laboratory appointment, score entry, resource utilization, etc.

2) Student: Students are the managed objects of the system, and their main permissions include course recommendation queries, learning interactions, and classroom recording functions.

3) Administrator: The administrator is the main management entity in the optimization management system, except for teachers, mainly responsible for laboratory management work, including equipment management and information management.

The service layer includes servers, campus networks, and routers. This layer is mainly responsible for implementing the service functions of the management system. The server can directly access the database, while users can query and download the entire system resources and information through the server. Users can also operate on the server to achieve control over different interfaces. The functional structure diagram of the service layer is shown in Figure 2.

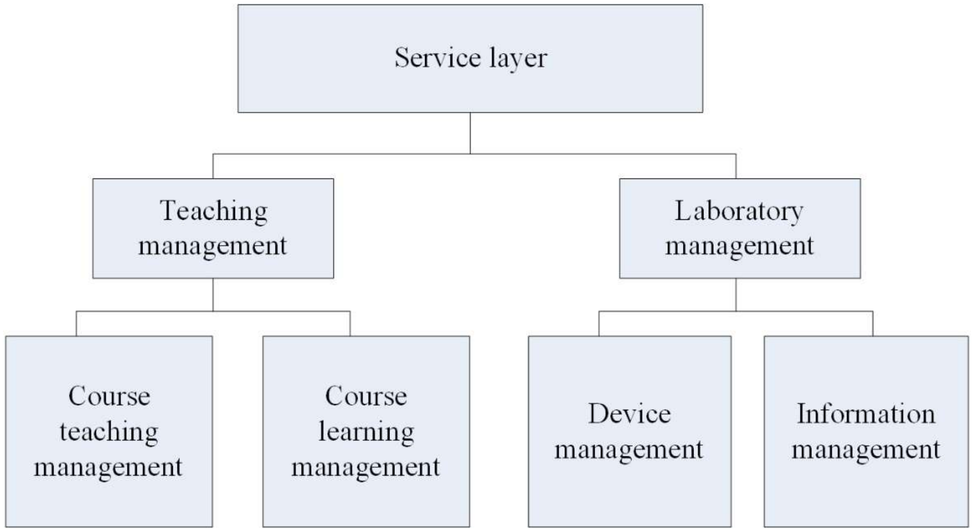

Fig. 2. Service layer functional structure

In Figure 2, the functional structure of the service layer is mainly divided into two parts: teaching management and laboratory management. In the teaching management function, according to the different service objects, teaching management is divided into course teaching management and course learning management. In the course teaching management, teachers can achieve three main functions: course scheduling, course adjustment, and laboratory appointment, as well as other auxiliary functions. In the course learning management module, students can implement course recommendation queries, learning interactions, and classroom recording functions according to their own needs.

The experiment management function is the heart of the functional structure of the system service layer, which is mainly divided into device management module and information management module. In the equipment management module, the system would perform equipment data exchange operations such as allocation, storage, and scrapping of computer experimental equipment recorded. After the operation is completed, the system would automatically generate a unique QR code. Except for students, teachers and administrators can scan this QR code to understand the specific information of the equipment. They can also adjust and configure the use of the equipment according to the specific needs of the work. The system would record its changes in detail. According to the allocation records, the historical usage of laboratory equipment resources can also be queried. In the optimization management system, the information management module can achieve database backup and recovery functions. Due to the complex usage environment of computer laboratory equipment, it is highly likely that malfunction events would occur during use. At this point, the information management module of the system can use nonlinear engineering algorithms to reinstall software on problematic computers, thereby building a secure and stable network environment. In order to reduce repetitive workload and improve information management efficiency, administrators can also download applicable network parameter configuration installation packages based on device configuration.

The system layer consists of a database and basic components. Database is the foundation of computer laboratory optimization management system. Under the concept of nonlinear engineering algorithms, the computer laboratory optimization management system uses multi thread response as the main response mode, which provides a clear division of labor among each thread. When a user access request occurs, some threads would respond directly according to the user's needs, while other threads would use the idle time of the foreground threads in the background to download the information and data required by the user from the server to the user layer of the system. When the program starts running, the backend thread also runs and sequentially downloads data from the server to the user layer according to the scheduling strategy.

The specific implementation method is: first, it is necessary to search for data in the downloaded service layer; once the data can be queried, the thread would collect it and process it accordingly. Afterwards, the data is transmitted to the system user layer. If the required data is not downloaded to the service layer, a backend thread would enter a standby or hibernation state and stop loading through scheduling. The corresponding thread would directly read the data from the server, and then process the read data and provide it to the system user layer. At the same time, the thread can also build local data in the foreground and wake up the backend program. After that, it grants data access permissions to the backend program. In this process, the foreground thread continuously waits for the next request instruction from the system, while the background thread continues to load data at the server layer according to the requirements of the system algorithm.

In the process of designing the database table structure, in order to meet the requirements of cohesion and coupling between modules of the computer public laboratory integrated management system, the user information data table and the experimental equipment data table are shown in Table 1 and Table 2.

Table 1. User information data table

Data Name	Data type	Byte	Not null or null
Identity	Bigint	20	Not null
User-name	Varchar	100	Not null
User-account	Varchar	50	Not null
User-password	Varchar	50	Not null
User-phone	Varchar	12	Not null
User-email	Int	50	Not null
Role	Tinyint	1	Not null

Table 2. Experimental equipment data table

Data Name	Data type	Byte	Not null or null
Identity	Bigint	20	Not null
Device-name	Varchar	100	Not null
Device-code	Varchar	100	Not null
Location	Varchar	100	Not null
User-name	Varchar	50	Not null
status	Int	1	Not null
Creat-time	Datatime	10	Not null

3. Computer Laboratory Optimization Management System Testing

To verify the effectiveness of the computer laboratory optimization management system based on nonlinear engineering, this paper conducted systematic testing on it. System testing is a verification of the successful implementation of a system. Through system testing, it is clear whether there are any vulnerabilities in the management system, whether data resources are secure, and whether related functions can be implemented. The main contents of the system test in this paper include function realization test, running load testing and security performance test. Table 3 is the software and hardware environment. To highlight the effectiveness of system testing, this article compared it with the existing traditional computer laboratory management system of a certain university, and the testing environment and content of the two systems were consistent.

Table 3. System test environment

Attribute	Item	Specifications
Hardware	Central Processing Unit (CPU)	Intel Core i9 9980XE 3GHz
	Random access memory (RAM)	16 Gigabyte
	Hard disk	480 Gigabyte
Software	Operating system	Windows Server 2019
	Database	Microsoft Structured Query Language Server 2019

1) Functional implementation testing. The functional implementation testing mainly focuses on the teaching management function and laboratory management function of the system. Its test cases include the nine categories of course scheduling, class schedule adjustment, lab reservation, course recommendation query, learning interaction, class record, equipment data exchange, database backup and database recovery (they are denoted by serial numbers in this paper as 1-9).

Taking the response time of test case requirements as an indicator, this paper compared the effect of functional demand response of two types of systems, as shown in Figure 3.

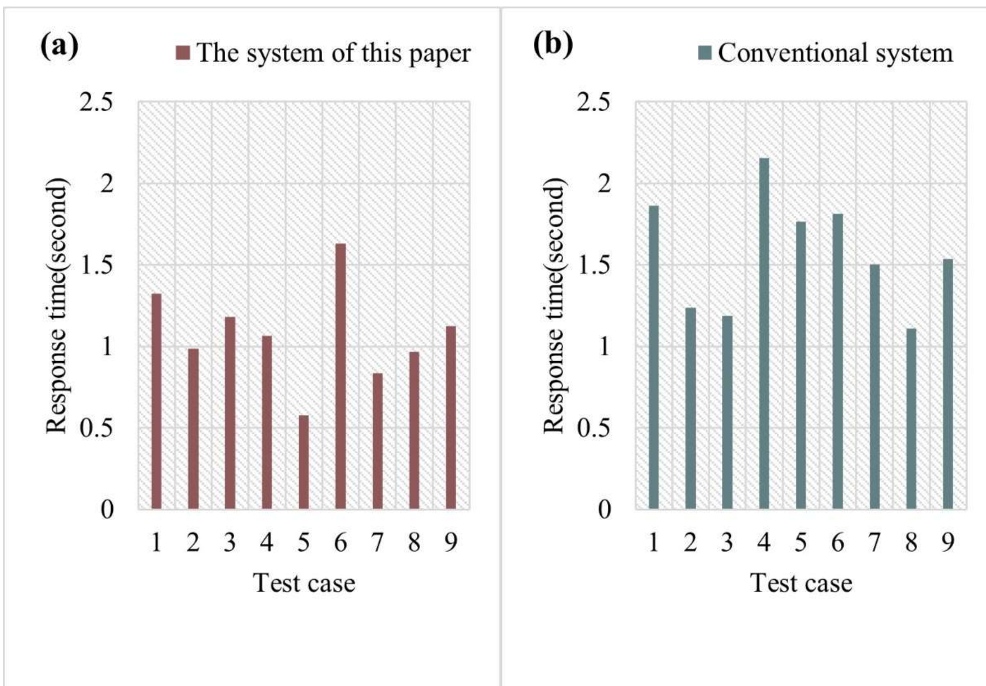

Fig. 3. Function implementation test results

Figure 3 (a) shows the functional implementation testing of the system in this article, and Figure 3 (b) shows the traditional system functional implementation testing.

From Figure 3, compared with the traditional computer laboratory optimization management system, the system in this paper had generally faster demand response time to each type of test case. In Figure 3 (a), the maximum demand response time of the nine types of test cases in this system was 1.6312 seconds, and the minimum was 0.5761 seconds; the average response time for each test case was 1.0767 seconds. In Figure 3 (b), the longest demand response time of the nine types of test cases of the traditional system was 2.1536 seconds, and the shortest was 1.1082 seconds; the average response time of each test case was approximately 1.5746 seconds. From the specific results, both systems could effectively meet the functional requirements of course scheduling, schedule adjustment, and laboratory appointment, but there were significant differences in response time. The optimization management system based on nonlinear engineering had a fast response time to various functional requirements, and the overall real-time performance of task processing was strong. With the support of nonlinear engineering algorithms, changes in system parameters were more sensitive to periodic response, resulting in higher efficiency in management work and task analysis.

2) Run load testing. The running load testing is mainly used to evaluate the performance level of the system. Through the detection of the running load condition of the system, the performance level of the system in practical applications can be effectively understood. This article recorded the CPU usage and RAM usage of two major systems during a specific time period under the state of simultaneous access by multiple users, as shown in Figure 4.

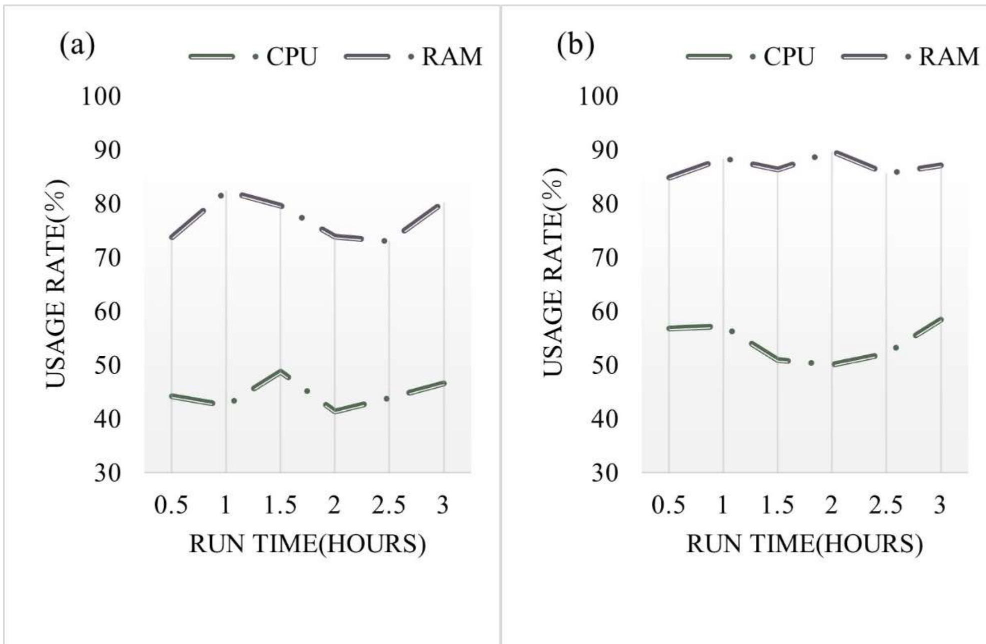

Fig. 4. Results of running load testing

Figure 4 (a) shows the system running load testing in this paper, and Figure 4 (b) shows the traditional system running load testing.

According to Figure 4, there was a certain gap in the CPU usage and RAM usage performance of the two major computer laboratory management systems during a specific time period. In Figure 4 (a), the average utilization rate of the optimized management system CPU based on nonlinear engineering during a specific time period was about 44.50%, and the average utilization rate of RAM was about 77.06%. In Figure 4 (b), the average utilization rate of the traditional computer laboratory management system CPU during a specific time period was about 54.20%, while the average utilization rate of RAM was about 86.95%. From the overall operating load situation, the utilization rate of CPU and RAM in the optimization management system under nonlinear engineering is relatively reasonable, and the overall operating load of the system is relatively balanced and stable. However, traditional management systems have high CPU and RAM usage rates, resulting in high system operating load pressure. The operating load state is closely related to system algorithms. Nonlinear engineering algorithms can effectively consider the nonlinear factors that exist in system operation, and their scheduling strategy has a low error level. The use of CPU and RAM can be stable within the normal range. However, the existing management systems in universities have high algorithmic complexity and high computational complexity, resulting in high utilization rates of CPU and RAM, thereby affecting the performance of the system in daily management of computer laboratories.

3) Safety performance testing. There is a large amount of equipment data and information resources in computer laboratories, and optimizing the security and reliability of management systems is of

great significance for avoiding management security risks and preventing data leakage. This article tested the vulnerability scanning range of the system in different network environments (with background traffic of 70Mbytes, 80Mbytes, 90Mbytes, and 100Mbytes respectively). The larger the scope of vulnerability scanning, the better the security performance of the system, and the smaller the risks and threats it faces. Figure 5 shows the results of the safety performance tests.

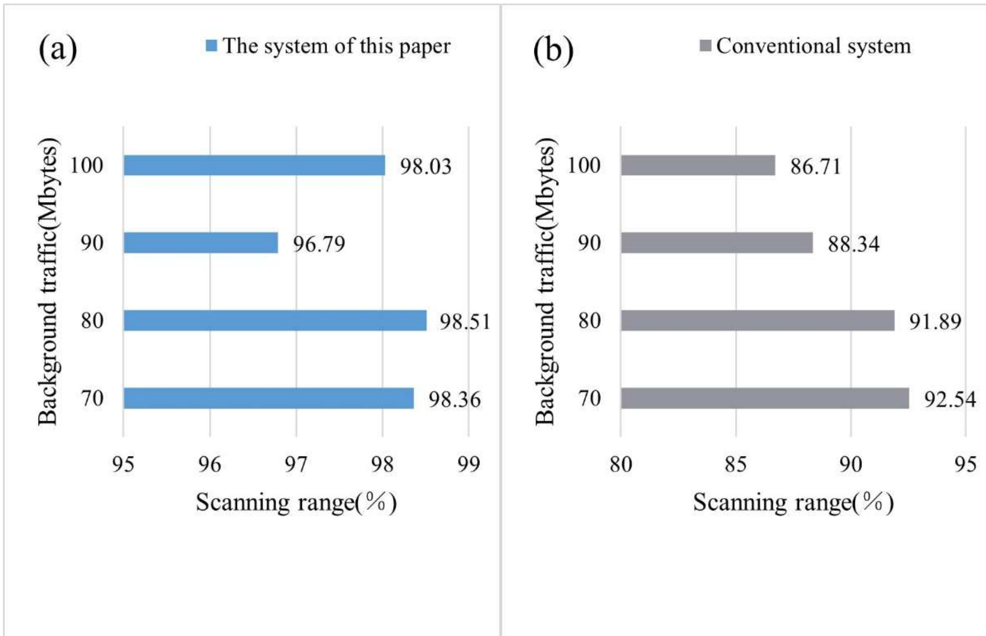

Fig. 5. Safety performance test results

Figure 5 (a) shows the system security performance test in this article, and Figure 5 (b) shows the traditional system security performance test.

From the security test results in Figure 5, it can be seen that the computer laboratory optimization management system based on nonlinear engineering had higher security performance under different background traffic. In Figure 5 (a), the scanning range of system vulnerabilities in this article was less affected by background traffic, with a maximum scanning range of 98.51%. Under different background traffic, the average scanning range of the optimization management system in nonlinear engineering was about 97.92%. In Figure 5 (b), the scanning range of traditional system vulnerabilities was greatly affected by background traffic, and its scanning range gradually decreased with the increase of background traffic, with a maximum scanning range of only 92.54%. Under different background traffic, the average scanning range of traditional computer laboratory management systems was 89.87%. According to comparison of specific security test results, the optimized management system under nonlinear engineering had strong security and reliability, which can scan system vulnerabilities on a large scale and provide effective protection for daily management work. However, traditional management systems had a small scanning range of vulnerabilities and were prone to risk events, thereby affecting the daily management effectiveness of the laboratory.

4. Conclusions

Computer laboratory management is an indispensable part of information education, and its design and construction are crucial for teaching management work. The day-to-day management of computer laboratories must not only match the needs of the development of information-based education, but also provide better services and guarantees for teaching and learning. In order to improve the current management effectiveness and level of computer laboratories, this article conducted in-depth research on the design of computer laboratory optimization management system based on nonlinear engineering. This not only improved the actual management efficiency of the system to a certain extent, but also improved the operating load of the system, significantly improving its reliability, security, and stability. Although the design of a computer laboratory optimization management system based on nonlinear engineering has a certain guiding role in promoting the healthy development of teaching management work, in the research process, this article still needs to improve the shortcomings and deficiencies. In future research, it is expected to further improve system functions, services, resource allocation, and dynamic integration, and promote the development of the system towards a more intelligent and scientific direction.

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