Design of a Web-Based Computer-Aided Teaching System for Fault Diagnosis

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Abstract. Traditional fault diagnosis methods usually rely on the experience and knowledge of professional technical personnel, which makes fault diagnosis often difficult and complex for non professionals. The design and research of computer-aided teaching systems aims to provide a more intuitive, interactive, and visual way to assist in fault diagnosis by combining computer technology and teaching methods. In order to improve the stability, user satisfaction, and information security of computer-aided teaching systems, a web-based fault diagnosis computer-aided teaching system is designed. Build a three-tier system structure based on B/S mode, including user interface layer, business logic layer and data access layer, focus on the design of foreground function module and background management module, so that the system has foreground and background management, online communication, data download and other functions, and select SQL Server 2000 as the system database. On the basis of hardware design, traditional genetic algorithms are improved to comprehensively consider the equality of teaching resource selection and the priority selection mechanism of local teaching resources in the selection of genetic genes, improve system work efficiency, and achieve user satisfaction in practical results. The experimental results indicate that the user satisfaction of this system is higher, and the system crash rate and personal information leakage rate are lower.

Keywords: Web · Fault Diagnosis · Assisted Teaching · Improved Genetic Algorithm · B/S Structure

1 Introduction

With the rapid rise and wide application of computer technology, multimedia technology and network technology, educational technology has entered a new stage of development, from traditional blackboard, tape recorder, slide and other conventional teaching mode of media means to multimedia teaching means based on computer and network technology. It has made a qualitative leap in learning style and educational design [1]. However, the rapid popularization of the network and the development of multimedia technology only provide the basic conditions for the network teaching, and it is not an easy thing to realize the network teaching. It has become a very necessary and urgent topic to make use of existing conditions and technologies to research and develop network assisted teaching

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systems that cooperate and complement each other with classroom teaching, to perfectly integrate classroom teaching and network teaching, to give full play to the auxiliary role of network in teaching, and to gradually improve online teaching technology and cultivate online teaching atmosphere [2, 3].

Reference [4] designed an embedded computer remote assisted teaching system based on web technology. The system hardware consists of memory, central processing unit, input device, and output device. The memory includes teacher side memory and student side memory. The central processing unit mainly consists of three parts: logic unit (ALU), control unit, and input/output unit. The software designs web server programs and database programs separately. To verify the effectiveness of the teaching system, a comparative experiment was designed, and the results showed that the system can effectively expand the auxiliary range and shorten the auxiliary time, but its security performance is poor and personal data information is easily leaked. Reference [5] designed a computer-aided classroom teaching system based on data mining. The data storage includes three parts: SARM storage, CD-ROM, and hard disk. An OLAP server is arranged, and a switch is used to integrate front-end tools and applications. On the basis of completing the hardware design, the massive information in the data source is classified using functions, and the hidden layer is calculated through the number of neurons to complete the design of a computer-aided classroom teaching system based on data mining. The experimental results show that the system has a higher number of concurrent users and a faster information retrieval time, but the sense of user experience is not strong, and the user satisfaction is not high. Reference [6] designed a method based on. NET platform of interactive electronic technology computer-aided teaching system, the system hardware structure by the user interface layer, business selection layer and data management layer of three layers of structure system. Teachers, students and other users enter their identity information in the user interface layer, log in to the system and enter the business selection layer, and click the corresponding program according to their application requirements. The business selection layer transmits the user selection instruction to the data management layer, and the data management layer selects the corresponding resources according to the user's requirements and feeds back to the user. The interactive mode of the system is mainly embodied in interactive teaching and information interaction. Interactive teaching is embodied in online teaching between teachers and students, and information interaction is embodied in information transmission. After testing, the system has strong anti-pressure ability and can respond to a large number of users' application instructions in real time, but the system has a high breakdown rate.

In response to the shortcomings of traditional auxiliary teaching systems, this article designs a web-based fault diagnosis computer-aided teaching system based on Web technology. The innovative points of this system design method are as follows:

(1) This system adopts a three-layer B/S architecture. Compared with the C/S architecture, the B/S structure does not increase any maintenance and upgrading workload regardless of the size of users or the number of branches, saving a lot of manpower and time.
(2) Design the front-end functional module and back-end management module of the system, and select SQL Server 2000 as the database of the computer-aided teaching system.

(3) On the basis of traditional genetic algorithms, the selection of genetic genes comprehensively considers the equality of teaching resource selection and the priority selection mechanism of local teaching resources, in order to improve work efficiency and achieve practical results that meet user satisfaction.

2 System Hardware Design

The computer aided instruction system designed in this paper uses modern information technology, based on a variety of media teaching resources and interactive means, to provide a good network learning environment centered on learners' independent learning. It fully embodies students' learning as the center, through providing various support services in the learning process of students, on the basis of improving the learning effect, to cultivate students' autonomous learning ability, collaborative learning ability and practical innovation ability.

2.1 System Mode Selection

Computers are the material foundation for designing web-based fault diagnosis computer-aided teaching systems. In the process of computer-aided teaching, computers serve as communication media between teachers and students. Web server is currently the most widely used and comprehensive type of server, based on Web technology. It refers to a computer program that provides teaching information browsing for web-based fault diagnosis computer-aided teaching systems in corresponding network environments. Students and teachers can send teaching requests, teaching files, and other data information through the server [7]. Generally speaking, a web server includes four working processes: establishing a connection, sending a request, issuing a response, and closing the connection. The working principle is shown in Fig. 1.

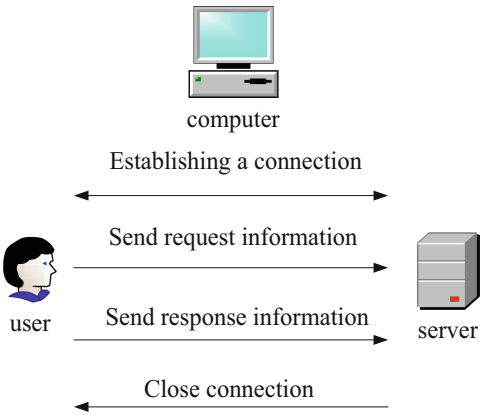

Fig. 1. Working Principle of Web Server

In Fig. 1, the established connection is realized by connecting the Web server and the browser through network protocol. The user can log in the browser to check whether the

connection is completed. Sending requests means that users send requests to Web servers through browsers, such as login requests, access requests, teaching requests and other required requests. After receiving the request, the Web server uses related algorithms to calculate and process the request, and finally transmits the result to the browser through the network protocol, and displays the request content while displaying the result. After the response is complete, disconnect the Web server from the browser and maintain and upgrade the Web server.

Previously, web-based systems often adopted two forms of architecture: C/S mode and B/S mode. Although the traditional C/S architecture adopts an open mode, it is only a level of openness in system development. In specific applications, both the client and server sides still require specific software, which fails to provide users with the open environment they truly expect. The B/S architecture products clearly demonstrate more convenient features [8]. No matter how large the user scale is or how many branches there are, there will be no additional maintenance and upgrading workload. All operations only need to be carried out on the server. If it is in a remote location, the server can be connected to the internet for immediate maintenance and upgrading, making upgrading and maintenance easier and simpler to use, saving a lot of manpower and time. Therefore, this system adopts a B/S structure.

The typical B/S mode application system network structure is shown in Fig. 2:

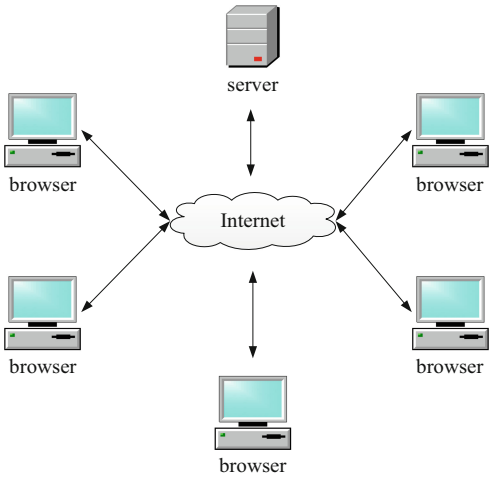

Fig. 2. B/S structure diagram

2.2 System Architecture

Based on the comparison of the advantages and disadvantages of C/S structure and B/S structure, this system adopts three layers of B/S architecture: user interface layer, business logic layer, data access layer.

(1) The user interface layer runs through Microsoft Internet Explorer or its compatible browser. Students, teachers and administrators operate on this layer.
(2) The business logic layer receives the user request input from the user interface layer, converts it into a way that the business logic process can understand, sends the data request to the data layer in an orderly manner according to the specific business logic, combines the data interpretation returned by the data layer into the information required by the user, and returns to the user interface layer. It is the core of realizing and processing business logic in the whole application software system [9]. Business logic layer is located in the Web Server and application server, in the server running Windows 2000 Server operating system, using ASP technology to develop all the system applications are placed on the server, when the user request comes, the Web server will request to the application.
(3) The data access layer is mainly the operation layer of the original data (database or text file and other forms of data storage), not the original data, that is, the operation of data, not the database. It manages data and provides a standardized open access interface to the business logic layer. The data access layer is located on the database server, where SQL Server 2000 runs. All databases of the system are placed on the server and managed by SQL Server 2000. This structure is conducive to system maintenance and load balancing, while also ensuring information security.

The system architecture diagram is shown in Fig. 3: The user interface layer receives input requests submitted by users, accesses the business logic layer, obtains access results, and sends them to users.

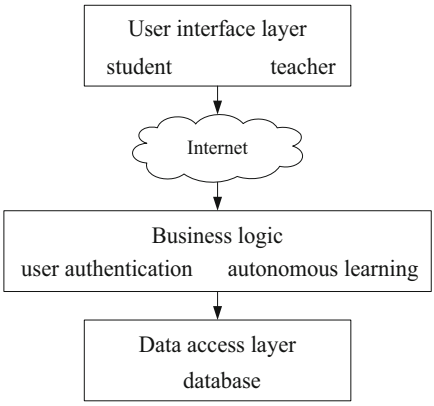

Fig. 3. System Architecture Diagram

2.3 Functional Module Design

The system is designed and developed using B/S mode, which can provide a comprehensive teaching system for teachers' auxiliary teaching and online course release; Students can query the teaching plans and video tutorials published by the teacher in the system,

and complete the practical training tasks of the relevant courses [10]. As a fault diagnosis training auxiliary teaching system, this system must have the following functions: front-end and back-end management, online communication, data download, and other functions. The following is the specific process of designing system functional modules:

(1) Front desk function module

The front-end users mainly perform operations such as logging in, registering, self-testing exercises, asking questions, downloading lesson plans, and entering virtual classrooms. The functional module diagram is shown in Fig. 4.

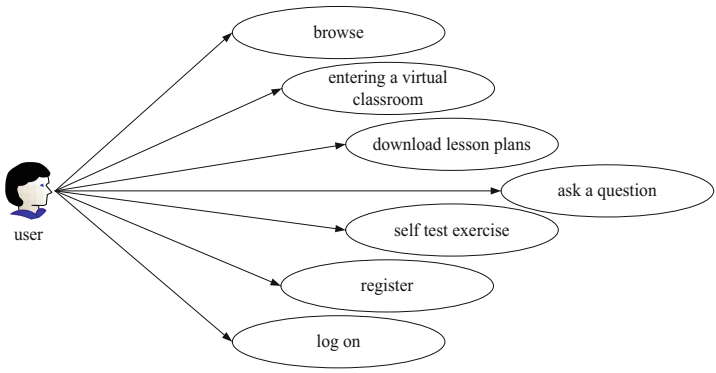

Fig. 4. Schematic diagram of the front-end functional module of the system

The foreground function module mainly includes the following functions:

1) Students log in

In order for the fault diagnosis computer aided instruction system to record the use of each student in detail, there must be a user login function. Specifically for the login module of the fault diagnosis training teaching auxiliary system, the addition of new users (teachers and students) is directly set by the system administrator in the background, and does not accept the user registration in the foreground.

2) Browsing function of teaching courseware and practical training tasks

Each student can click the relevant links in the system to learn the corresponding teaching courseware and browse the training tasks. On the one hand, this helps students consolidate the knowledge they have learned, on the other hand, it helps students understand the needs of fault diagnosis in work from the perspective of practical training.

3) Download function of teaching courseware and practical training materials

Each student can search for the teaching courseware or training task materials they want to download in the system, and then download them locally for offline learning.

4) Upload graphic and video tutorials

Both teachers and students can upload resources such as graphic and video tutorials through the front desk, fill in the title when logged in, and set the classification and upload type to upload. After uploading, student users need to go through the administrator's backend review before publishing, while teachers can directly upload and display teaching resources on the front desk.

5) Online communication

If students encounter questions they do not understand during the learning process, they can go to the online communication bar to send out questions and wait for answers from teachers or other classmates. They can search for questions through keywords. In the logged in state, users can easily post replies to view the content of their posts.

6) Member center management

Both teachers and students can log in to the member center to manage related matters, including memos, messages, teaching courseware, homework, training tasks, etc.

7) System Bulletin

System administrators can release, modify, delete and other operations of announcements in the background, and then the foreground user first time to understand the latest announcement content.

(2) Background management module

When the system administrator and teacher log in to the background management page, the authentication of the system administrator and teacher is added. Once the user name and password information in the session is empty, it indicates that the teacher or administrator has not logged in. At this time, a dialog box will pop up, indicating that the user has not logged in. If the login succeeds, you can enter the background to manage the system. The system administrator can recommend the top of the fine course, key training tasks, can delete expired, useless content, can batch reply to students' questions.

Background management flow chart is shown in Fig. 5.

2.4 Database Technology

The computer-aided teaching system, like other Web-based systems, cannot do without the support of a backend database. The backend database is mainly used to access various information and data on the website, such as using a student data table in the database to save various basic information of students, using a test question table to save various test question information, and using a message table to save message information. The database is the basic guarantee for realizing the system's dynamic interaction function. In the selection of backend databases, different requirements can be met by selecting different databases. Currently, Access and SQL Server are two commonly used database management systems.

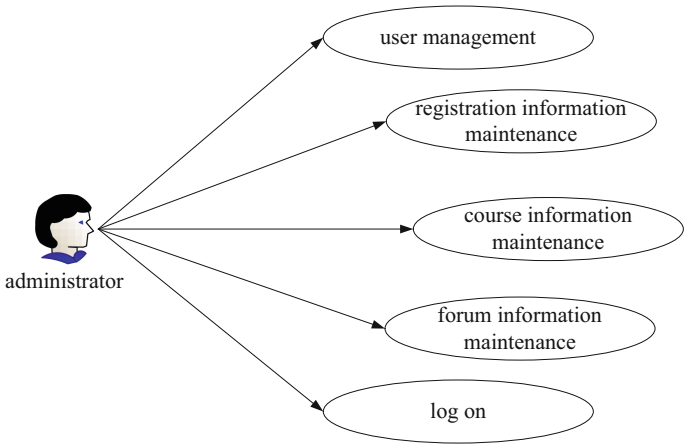

Fig. 5. Schematic diagram of system backend management module

Access is a desktop database management system, it is simple to operate, easy to use, the whole system only needs a "*.mdb" database file to achieve the storage and Access to the data, when the website data volume is small, the page view is small, can choose Access, but when the system data volume is large, the number of visitors, Access has certain limitations.

SQL Server 2000 is a high-end database management system and is currently one of the most popular database service systems. SQL Server itself is a member of Microsoft office components. It is organically combined with other Microsoft software (Windows Server, Internet Information Server, etc.), and makes full use of the services or functions they provide (such as security management, event log, performance monitor, memory management, asynchronous, etc.); SQL Server 2000 also provides built-in data replication capabilities, powerful management tools, and an open system architecture; The SQL Server 2000 relational database engine supports the functions required by today's demanding data processing environment. The database engine fully protects data integrity and provides more secure and reliable storage functions for relational data and structured data. It has a good set of security control mechanisms to ensure the security of databases and data in databases and prevent some problems, such as, It can prevent multiple users from attempting to update the same data at the same time; SQL Server 2000 can provide the database services required for ultra large systems, and can simultaneously manage thousands of concurrent operations to minimize the user cost of modifying the database, thus occupying the least system resources. Overall, the computer-aided teaching system designed in this article uses SQL Server 2000.

3 Improve the Application of Genetic Algorithm in Computer Aided Instruction System

Through the above steps, the hardware design of computer aided instruction system for fault diagnosis based on Web is completed. Then, from the point of view of algorithm design, the system of this paper is further improved. The computer aided instruction

system for fault diagnosis based on Web is oriented to more users and contains more extensive resources. In the face of many users' differentiated requests for massive data, it is very difficult to design computer aided instruction system for fault diagnosis based on Web, and the main difficulty lies in how to improve user response efficiency. On the basis of traditional genetic algorithm, various kinds of teaching resources are optimized and classified respectively. In the selection of genetic genes, the equality of teaching resources selection and the selection mechanism of local teaching resources are considered comprehensively, so as to improve the work efficiency and achieve the actual effect of user satisfaction.

The Web - based fault diagnosis computer aided instruction system improves the traditional genetic algorithm in task scheduling. The key gene selection link in the genetic process increases the constraint mechanism which combines the equality of access resources and the principle of local resource preference.

(1) Chromosome coding and decoding

Based on the comprehensive analysis of the characteristics of direct chromosome coding and indirect chromosome coding, combined with the characteristics of Web-based computer-aided teaching system for fault diagnosis, the resource-task based indirect coding method is selected here: the number of subtasks is taken as the length of chromosome, and the number of genes in chromosome is taken as the number of resources allocated by corresponding subtasks. Assuming that the number of tasks facing the system is K, the number of processing points is M, and the assignment of tasks at a is $TaskNum(a)$, then the total number of subtasks can be calculated by formula (1):

$$SumTaskNum(a) = \sum_{a=1}^{K} TaskNum(a) \tag{1}$$

Next, these tasks need to be renumbered, as shown in formula (2):

$$N = \sum_{a=1}^{K} TaskNum(a) + k \tag{2}$$

Finally, the completion time of each job and the total completion time of all jobs are calculated by decoding the data, ETC matrix and DTC matrix.

The calculation method of completion time of each assignment t is shown in Formula (3):

$$Time(t) = \sum_{i,j=1}^{p} TaskTime(i, j) \tag{3}$$

Among them, p is the location where task i in task t is assigned to the computing node, and $TaskTime(i, j)$ is the time when task i completes sub task j on the computing node p.

The calculation method for the completion time of the total task is shown in formula (4):

$$TotalTime = \sum_{i,j=1}^{n} NodeTime(i,j) \tag{4}$$

where, $NodeTime(i, j)$is the time it takes a compute node to complete tasks i and j , and n is the number of tasks for a compute node.

(2) Initial population generation

Here, it is assumed that the population size is R, there are m processing points, z jobs and a total of U subtasks. The first step should be to use the Max-Min algorithm to equally limit the allocation of system resources, and then randomly generate the required chromosomes. At this time, the number of chromosomes is R, the length is U, and the value interval of genes is limited to $[1, m]$.

(3) Fitness function

Genetic algorithm calculates the advantages and disadvantages of individuals through fitness function, and selects and evolves the next generation to seek the optimal solution of the problem.

The satisfaction level of users with the completion time of all assignments in individual c is shown in formula (5):

$$f_1(i) = g(i)/K \quad 1 \le i \le R \tag{5}$$

The fitness of total task completion time is shown in Formula (6):

$$f_2(i) = 1/c(i) \quad 1 \le i \le R \tag{6}$$

According to formulas (5) and (6), outstanding individuals with relatively high fitness values can be selected and given to the next generation.

(4) Genetic manipulation

Genetic operations are divided into three types: selection, crossover, and mutation, which are the main ways to select and produce the next generation of individuals. Selection operation is a fundamental way to spread excellent genes in a population. When selecting an operator, use the roulette wheel selection method. Use the following formulas (7) and (8) to calculate the probability of each individual being selected one by one using the previous formulas (5) and (6):

$$P_1(i) = f_1(i) / \sum_{j=1}^{R} f_1(j) \tag{7}$$

$$P_2(i) = f_2(i) / \sum_{j=1}^{R} f_2(j) \tag{8}$$

Variations can create new search Spaces. The crossover probability function and mutation probability function are shown in Formula (9) and Formula (10) respectively:

$$P_c = \begin{cases} k_1 \left(f_{\max} - f'\right) / \left(f_{\max} - f'\right), f' \geq f_{avg} \\ k_1, \qquad\qquad\qquad\qquad f' < f_{avg} \end{cases} \tag{9}$$

$$P_m = \begin{cases} k_3 (f_{\max} - f) / \left(f_{\max} - f_{avg}\right), f \geq f_{avg} \\ k_4, \qquad\qquad\qquad\qquad f < f_{avg} \end{cases} \tag{10}$$

Among them: f is the individual to be mutated; $f_{\max}$ is the largest individual in the group; f_{avg} is the average value of each generation of population.

The application of improved genetic algorithm in web-based fault diagnosis computer-aided teaching system lies in the allocation and scheduling of system resources for numerous remote user tasks. This article studies the architecture of web-based fault diagnosis computer-aided teaching system and improves the original adaptive genetic algorithm based on the characteristics of multi user and multi task types in web-based fault diagnosis computer-aided teaching system, Based on the traditional genetic algorithm, the genetic gene is selected by integrating data fairness and local sexual selection. Compared with the traditional algorithm, it is more efficient in responding to users' demand response.

4 Experimental Analysis

To verify the feasibility of a Web-based computer-aided teaching system for fault diagnosis, system performance verification was conducted.

4.1 System Operating Environment

According to the overall demand of the computer aided instruction system, in order to ensure the efficiency and reliability of the system operation, the server side of the system should have high hardware and software configuration. This application can run on the Internet, can also be applied to the campus network and connected to the internal LAN computer room, its operation requirements are as follows Table 1:

Table 1. System hardware and software environment

Parameter	Specification
Server	CPU: P4-3.2G
Operating system	Windows 8
WEB server	Microsoft Internet Information Server 6.0
Development tool	ASP
Memory	512 M
Network routing protocol	AODV protocol
Video card	NVIDIA

In the above operating environment, system performance verification was carried out. In order to make the experimental results more reliable, a computer-assisted classroom teaching system based on data mining and an interactive electronic technology computer-assisted teaching system based on the. NET platform were used as comparative systems to compare with the system in this paper.

4.2 Analysis of Experimental Results

4.2.1 Personal Information Leakage Rate

Computer aided instruction system is very important in the management of personal information. Therefore, the leakage rate of personal information is taken as an experimental indicator to compare the three systems, and the results are shown in Fig. 6.

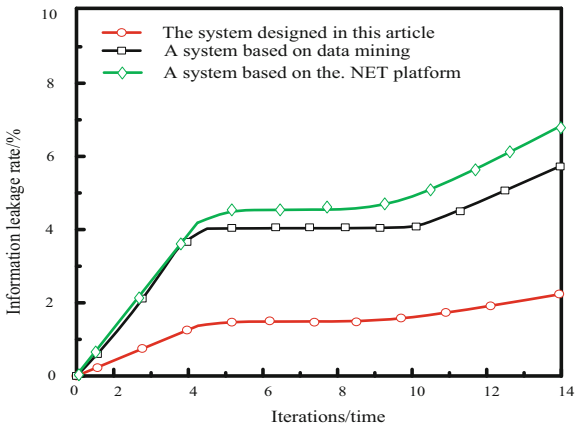

Fig. 6. Comparative results of personal information leakage rate

From Fig. 6, it can be seen that from the perspective of personal information leakage rate, the highest personal information leakage rate of the system in this article is

only 2.3%, while the highest personal information leakage rates of the computer-aided classroom teaching system based on data mining and the interactive electronic technology computer-aided teaching system based on the. NET platform are 5.7% and 6.4%, respectively. From the above data, it can be seen that the personal information leakage rate of the system in this article is lower, which can maximize the protection of user privacy information and improve the security of user information.

4.2.2 Comparative Analysis of System Crash Rate

If the system crash rate is too high in the application process, the user experience will be affected. Therefore, the system crash rate is taken as the experimental index to test the system crash rate of the three systems. The comparison results are shown in Fig. 7.

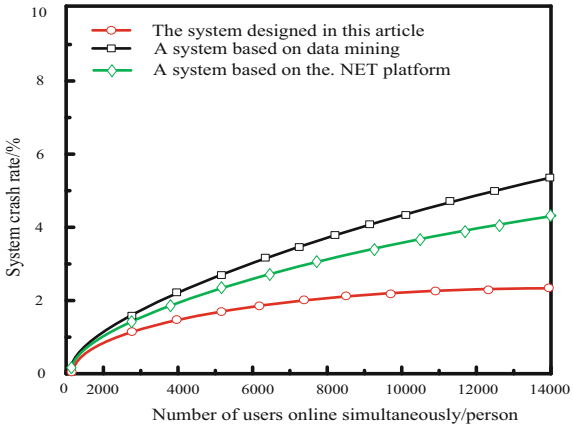

Fig. 7. Comparison results of system crash rates

As shown in Fig. 7, as the number of users simultaneously online increases, the crash rates of the three systems gradually increase. Relatively speaking, the crash rate of the system in this paper is the lowest and consistently lower than that of the other two systems. Through comparison, it can be seen that the system in this article can improve the stability of the system, and the probability of system failure is relatively low.

4.2.3 Comparative Analysis of User Satisfaction

Select students and teachers from the faulty major to evaluate the application effectiveness of the three systems through scoring. The user satisfaction comparison results of the three systems are shown in Table 2.

From the data in Table 2, it can be seen that users have higher satisfaction with the system in this article, with a maximum score of 90.6 points. However, the systems based on data mining and the. NET platform have a maximum score of 86.3 points and 79.5 points, respectively. From this, it can be seen that users are more satisfied with the effectiveness of the system in this article, indicating that the system is more in line with users' expected goals and meets their actual needs.

Table 2. Comparison results of user satisfaction

Number of users/name	User rating/score		
	The system designed in this paper	System based on data mining	System based on .NET platform
100	90.6	86.3	79.5
200	89.7	84.0	75.3
300	88.5	82.1	74.2
400	87.0	79.5	73.0
500	86.3	76.3	72.9

5 Conclusion

In order to improve the stability of computer aided instruction system, improve user satisfaction and user information security as the research goal, design a fault diagnosis computer aided instruction system based on Web. The experimental results show that users have higher satisfaction with the system, and the highest score is 90.6. The breakdown rate of this system is the lowest and always lower than that of the other two systems. The highest personal information leakage rate of the system in this paper is only 2.3%, much lower than the other two systems. It shows that the application effect of this system is better and can meet the needs of users. Although the system designed in this article has improved the effectiveness of computer-aided teaching for fault diagnosis to a certain extent, the response speed of the system still needs to be improved, and further research will be conducted in the future to address this issue.

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References

1. Zhang, T., Xu, M., Liu, C.: Design of physics multimedia assisted teaching system based on concept network. Mod. Electron. Tech. **43**(20), 119–121+125 (2020)
2. Wang, H.-J., Wang, Z.-F.: Design of simulation teaching system based on modular production and processing. Comp. Simul. **39**(04), 205–209 (2022)
3. Chen, J.-Y., Wang, Z., Chen, J.-Y., Chen, Z.-Q., Zhen, H.-B.: Design and research on intelligent teaching system based on deep learning. Comp. Sci. **46**(1), 550–554+576 (2019)
4. Yin, J., Yin, L.: Design of embedded computer remote auxiliary teaching system based on Web technology. Mod. Electron. Tech. **44**(16), 25–29 (2021)
5. Chen, G., Li, Y. Lv, X.: Design of computer-aided classroom teaching system based on data mining. Mod. Electron. Tech. **43**(04), 94–96 (2020)
6. Cao, L.: Interactive computer aided teaching system based on .NET platform. Mod. Electron. Tech. **43**(03), 134–137+141 (2020)
7. Wang, B., Zhao, M., Fan, Z.: Design of automatic adjustment teaching system based on network. Mach. Tool Hydraulics **50**(02), 109–113 (2022)

8. Guo, W., Wang, B., Zhao, D.-P.: Design of experimental teaching system for hydraulic control valve performance based on network. Chin. Hydraul. Pneumatics **47**(01), 122–128 (2023)
9. Sheng, W.: Design and implementation of digital holographic comprehensive experiment system for teaching. Coll. Phys. **38**(05), 45–47 (2019)
10. Qi, X., Han, L.: Design and implementation of android assistant teaching system based on web service. Microcomput. Appl. **37**(08), 6–8 (2021)