



Multi Agent Based Network Collaborative Learning Support System for Mathematics Curriculum

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Abstract. In the process of designing the learning support system, due to the low interaction flexibility between different modules, the running performance of the system is difficult to meet the application requirements under the condition of multi-user parallelism. Therefore, this paper proposes the design and research of multi-agent based mathematics curriculum network collaborative learning support system. The MYC-J335X-V2 core board equipped with TI AM335X processor and ARM Cortex-A8 core is used as the carrier of system development, ensuring that the running performance meets the application requirements under multi user parallel conditions. In the software design phase, based on multi-agent, a three-tier system architecture is constructed, and the resource allocation of each level is clarified. Each agent is refined from the perspective of structure and function, so that the information interaction between agents can be carried out independently, and its flexibility is improved. In the test, on the premise of 1400 concurrent requests, the corresponding CPU utilization and response time of the design system were 67.3% and 466.3 ms, respectively, which met the application requirements of the mathematics course network collaborative learning support system.

Keywords: Multi-Agent · Mathematics Curriculum Network · Support System · MYC-J335X-V2 Core Board · System Architecture · Information Interaction

1 Introduction

Compared with the traditional classroom, the information-based classroom has more resources, richer forms of interaction [1], and more wonderful forms of classroom expression, which can improve teachers' teaching and office efficiency, strengthen the interaction between teachers and students, and improve students' interest in learning [2]. Through the information classroom, students' data can be collected and analyzed, and students' learning behavior can be supervised. Students can use the information platform to use fragmented time for learning [3], and teachers can use the information platform to reduce workload and conduct personalized teaching for students. As the epidemic has made the information-based classroom a big step forward, various teaching systems have

sprung up like mushrooms [4]. Although this type of teaching system has various functions, its functionality is not highly targeted, and most teachers only use a small portion of these functions in actual teaching practice. As reference [6] analyzes the steady and long-term development of online teaching in the new era - taking the practical courses of music majors in universities as an example, reference [7] designs a new visual Q&A based online teaching effectiveness evaluation model. The above research shows that teachers are unable to customize the interface or the functions provided in the course according to the characteristics and different needs of their own courses, and the complex functional interface can actually lead to a decrease in user experience. Therefore, it is of great value and significance to design and implement a personalized teaching system that teachers can customize according to the characteristics of the mathematics curriculum.

For this reason, this paper proposes the research on multi-agent based mathematics mathematics curriculum network Collaborative learning support system, and the specific research process is as follows:

- (1) The hardware design includes the design of a processor and a development board, ensuring that their performance meets the application requirements under multi user parallel conditions;
- (2) In the software design, the multi-agent system architecture and the structure and function design of each agent are designed respectively to ensure the support effect of the network Collaborative learning of mathematics courses;
- (3) The test experiment analyzed the server performance under different numbers of concurrent accesses, and verified the practical application effect of the designed system.

2 Hardware Design

In order to ensure that the designed mathematics course network collaborative learning support system can meet the operational requirements under the multi-objective application environment, realize the rapid parallel processing of multiple requests, and reasonably design the core board is very necessary [8]. For this reason, this paper takes MYC-J335X-V2 core board as the development carrier of the design system, which is equipped with TI AM335X processor, with strong compatibility and easy expansion attribute characteristics [9]. At the same time, the ARM Cortex-A8 core is also configured, and the corresponding operating frequency can be up to 1.0 GHz. With the characteristics of high performance and low power consumption, it can provide the highest DMIPS at the same cost; At the same time, it provides 3D graphics acceleration and key peripheral integration to meet various application needs [10]. The optional 3D graphics accelerator has a performance of up to 20 M/tri/s, supports LPDDR1/DDR2/DDR3 memory, and the independent PRU subsystem provides additional flexibility for product design. In terms of resource allocation, the MYC-J335X-V2 core board integrates gigabit Ethernet interface chips and PMU power management chips, which can meet the development and design requirements under different conditions.

The temperature of MYC-J335X-V2 core board's operating environment is required to be industrial grade, which can perfectly meet the external connection and expansion

needs with the support of 200PIN golden finger interface. In terms of software resource configuration, the MYC-J335X-V2 core board perfectly supports the Linux 4.1.18 system. Combined with the above configuration analysis, it can be seen that MYC-J335X-V2 core board can meet the operation management requirements of the mathematics course network collaborative learning support system. In addition, the MYC-J335X-V2 core board also provides optional support for Ethercat and Profibus to further meet the needs of system design.

(1) Integrated configuration and extended signal settings

The specific structure of MYC-Y335X-V2 core board is analyzed. It is designed as a high-density high-speed circuit board, connected by stamp holes, with a size of 70 mm × 50 mm. The board is integrated with TI AM3352/AM3358 processor, DDR3, NandFlash, PHY chip (gigabit) and other circuits. See Fig. 1 for details.

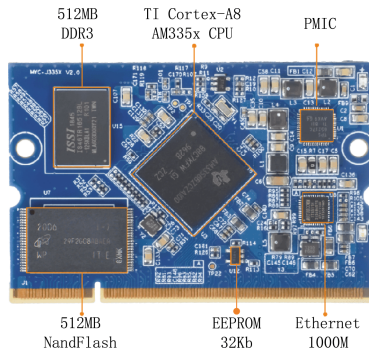


Fig. 1. MYC-Y335X-V2 Core Board Integration Configuration

In order to meet the integration requirements, MYC-Y335X-V2 core board adopts 8-layer PCBA design, gold deposition process, and independent and complete ground plane to ensure its quality reliability. On this basis, the extended signal setting of MYC-Y335X-V2 core board is analyzed, as shown in the table (Table 1).

It can be seen from the MYC-Y335X-V2 core board expansion signal settings shown in Fig. 1 that it has rich signal resources and can meet its application needs with strong scalability.

(2) Functional configuration

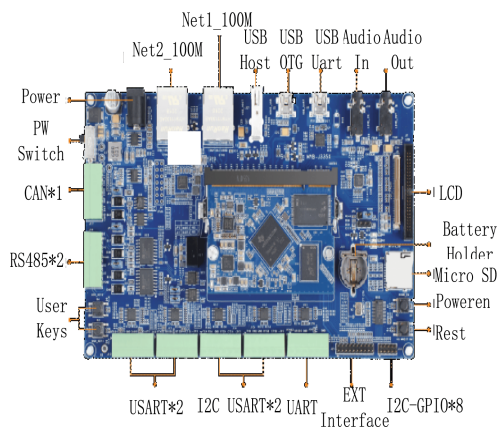
Figure 2 shows the function configuration of MYC-Y335X-V2 core board.

It can be seen from the information shown in Fig. 2 that the MYC-Y335X-V2 core board supports the implementation of multiple functions and can ensure the smooth operation of the network collaborative learning support system for designing mathematics courses in a multi-agent environment. Table 2 shows the parameter configuration of the MYC-Y335X-V2 core board backplane.

As can be seen from Table 2, the MYC-Y335X-V2 core board designed in this paper has multiple configuration parameters to choose from, which greatly ensures that it can meet the development needs of different levels.

Table 1. MYC-Y335X-V2 Core Board Extension Signal Settings

S/N	project	parameter
1	Internet port	2-way gigabit network interface
2	USB	Expandable 2-way independent USB OTG2.0
3	Serial port	Expandable 6-channel serial port
4	I2C	Expandable 2-way I2C bus
5	CAN	Up to 2-way CAN bus can be expanded
6	SPI	Expandable 2-way SPI
7	ADC	8-way ADC
8	PWM	2-way PWM
9	SDIO	3-channel SDIO (1 channel SDIO signal is shared with NAND FLASH signal)

**Fig. 2.** Function Configuration of MYC-Y335X-V2 Core Board

(3) Parameter configuration

Table 3 shows the basic parameter configuration of MYC-Y335X-V2 core board.

Combined with the data information shown in Table 3, MYC-Y335X-V2 core board can realize the adaptive adjustment of its own running state in combination with the actual application of the mathematics course network collaborative learning support system to ensure that the system performance can meet the actual needs. In the actual operation stage, considering the differences of the objective environment, it is also extremely necessary to ensure that the performance configuration of the core board can adapt to the actual situation of different operation environments. Table 4 shows the basic operation parameter configuration of MYC-Y335X-V2 core board.

It can be seen from Table 4 that the adaptability of MYC-Y335X-V2 core board to the operating environment is of industrial grade, and it is characterized by low power

Table 2. Parameter Configuration of MYC-Y335X-V2 Core Board Bottom Plate

S/N	project	parameter
1	audio frequency	One channel audio 3.5 mm output interface; One channel audio 3.5 mm input interface
2	display	16 bit true color display interface, default 480 × 272 resolution (4.3 inch screen), support 7 inch screen (800 * 480)
3	USB	1-way high-speed USB HOST interface
4	Serial port	1-way mini USB HOST/Device interface
5	RS485	1-channel mini USB debugging interface
6	Micro SD	5-way serial port, 1-way 3-wire, 4-way 5-wire
7	CAN	2-way RS485 interface, shared by signal and serial port
8	Ethernet	1-way Micro SD card interface
9	JTAG	1 circuit (with electrical isolation)
10	User light	2-way 10/100/1000 Mb/s Ethernet interface
11	RTC	One 14-PIN, 2.54MM spacing JTAGP
12	project	2 user lights/system heartbeat lights (backplane: green)

Table 3. Basic Parameter Configuration of MYC-Y335X-V2 Core Board

S/N	name	main parameter
1	Core and main frequency	TI AM3352/AM3354/AM3358 up to 1 GHz
2	Memory	128 MB / 256 MB / 512 MB DDR3
3	Flash	128 MB / 256 MB / 512 MB NandFlash
4	eMMC	8 GB eMMC standard configuration, 16 GB and 32 GB capacity options
5	Ethernet	1 channel gigabit network interface
6	Power management	External PMU power management chip
7	watchdog	External independent hardware watchdog
8	indicator light	One power indicator (red) and one user indicator (green)

consumption. With this configuration, the impact of environmental factors on system operation status is minimized. In addition, MYC-J335X-V2 provides driver support for the Linux operating system, along with development kits and related materials. It provides stable design reference and perfect software development environment for developers, which can effectively help developers improve development efficiency, shorten development cycle, optimize design quality, and accelerate product development and time to market. The Boot Loader is set as Boot Loader, and the secondary boot program is responsible for system initialization and kernel boot.

Table 4. Operation Parameter Configuration of MYC-Y335X-V2 Core Board

S/N	project	parameter
1	working temperature	-40~+85 °C industrial grade
2	ambient temperature	-50~100 °C
3	ambient humidity	20%~90%, non condensing
4	Mechanical dimensions	67.6 mm × 45 mm, 1.00 mm thick
5	PCB specification	8 layers, produced by gold deposition process, independent grounding signal layer, lead-free
6	Power supply	DC 5 V
7	Core board interface type	200PIN golden finger interface, spacing 0.6 mm
8	System power consumption	About 5 V/0.1 A

It not only supports NAND Flash erasing, reading and writing, but also supports downloading images on the network, setting and saving environment variables, displaying, comparing and modifying memory contents, and adjusting system operation with bootcmd, bootargs and other settings.

(4) Driver settings and application configuration

Table 5 shows the drive configuration of MYC-J335X-V2 core board.

Table 5. MYC-J335X-V2 Core Board Drive Settings

S/N	set up	Drive configuration
1	USB Host	Linux kernel specially designed for MYD-AM335X-J hardware
2	USB Device	USB Host drive, supporting OHC and EHCI transmission modes
3	Ethernet	USB Device Driver (Gadget)
4	MMC/SD	Ethernet drive
5	NAND Flash	MMC/SD card driver
6	I2C	NAND Flash/SmartMedia driver
7	PI	I2C drive
8	Audio	SPI drive
9	LCD	SGTL5000 audio driver
10	RTC	LCD screen drive, supporting 4.3 inch and 7 inch LCD screens
11	TouchScreen	Built in RTC clock drive
12	PWM	4-wire resistance touch screen drive

(continued)

Table 5. (continued)

S/N	set up	Drive configuration
13	UART	PWM drive
14	CAN	Serial Drivers
15	PMU	CAN drive
16	LED	Power management drive
17	GPIO	LED drive. Including GPIO LED and PWM LED drive
18	I2c to UART/IO	GPIO drive

On this basis, the file system is divided into rootfs and rootfs qt. Among them, rootfs is based on the file system driver customized by buildroot, and rootfs qt uses the Qt file system.

To drive, both are in binary form. For the corresponding application configuration, the specific settings of the MYC-J335X-V2 core board are shown in Table 6.

Table 6. MYC-J335X-V2 Core Board Application Configuration

S/N	set up	to configure
1	Audio	Aduio test program
2	CAN	CAN test procedure
3	Key&LED	Key LED test procedure
4	NET	Network Test Procedure
5	RTC	RTC clock test experiment
6	NAND Flash	NAND Flash Clock Test Experiment
7	GPIO	GPIO Test Procedure
8	RS485	RS485 Test Procedure
9	Qt	Qt environment and demo program

Combined with the above comprehensive analysis of MYC-J335X-V2 core board, it can be seen that taking it as the development carrier of the web-based collaborative learning support system for the design of mathematics courses in this paper can effectively guarantee the smooth implementation of relevant functions and improve the reliability and smoothness of its operation.

3 Software Design

3.1 System Architecture Design Based on Multi-agent

The system studied in this paper adopts browser/agent/server server mode (and B/A/S mode). The browser is used to let users browse the page, and the server is used to store the database, mainly.

It is used to process applications and systems and interactively access the corresponding data in the database. This mode is called “thin user” mode. Users can surf the Internet through the browser, which can avoid installing different user programs for different clients, help to improve users’ access speed, and is equivalent to providing a unified environment for users. In order to reduce the burden of the server, the client can also install some Java Applet plug-ins to improve the functions of the client, which not only increases the security, but also can perform corresponding operations on the user according to the permissions granted by the user. All agents are distributed in the intermediate agent layer, which is the communication bridge between the server and the client. Server communication requires protocols such as FTP and HTTP to assist. Various agents communicate on the intermediate agent layer through FIPA-ACL language.

The first layer of the system architecture is the presentation layer, which mainly provides the user with a Web browser, presents it to the user graphical interface, and is responsible for interacting with the user. The display logic of the system also includes the presentation layer. The main functions of this layer are to provide user information and behavior acquisition, realize the input and output of knowledge required for mathematics teaching, accept the tasks provided, and process the feedback results.

The intermediate agent layer is on the second layer of the system architecture. These agents are mainly divided into three types, which can be expressed as

$$S_a = \{a_y, a_g, a_r\} \quad (1)$$

Among them, S_a Represents the agent of the intermediate agent layer, a_y Represents the user agent, which can be subdivided into

$$a_y = \{a_{yt}, a_{ys}\} \quad (2)$$

Among them, a_{yt} Represents teacher agent, a_{ys} Represents a student agent. a_g Represents the management agent, which can be subdivided into

$$a_g = \{a_{gj}, a_{gt}\} \quad (3)$$

Among them, a_{gj} Stands for monitoring agent, a_{gt} Represents the mathematics teaching management agent. a_r Represents a task agent. The main workflow of agents in the middle agent layer is as follows:

- (1) When logging into the system for the first time, you need to register through the monitoring agent, assign different permissions to users with different identities, generate teacher agents for teachers, and student agents for students;
- (2) After the student agent logs in the system for the first time, it extracts the basic information of the user according to the user’s identity, and uses this information as the user’s system learning scheme;

- (3) If the student is not logging in to the system for the first time, extract the learning record agent according to the student agent, and give the learning record saved by the student before, which can be used as the reference information for the student to continue learning;
- (4) After students log on to the system, they can select their own course content according to the displayed learning interface. At the same time, the management agent also receives the information obtained by the student agent, and provides students with learning suggestions according to the student agent;
- (5) After the teacher agent logs into the system, he can edit the syllabus and lesson plan, and assign homework, exam questions, correct homework, answer questions raised by students, etc. to the student agent of the course he has learned;
- (6) The specific contents learned by students, exercises or assignments after class, solutions to problems encountered in learning, and examination questions after each chapter are provided by the mathematics teaching agent, homework agent, question answering agent, and examination agent respectively;
- (7) Student Agent integrates the mathematics teaching agent, homework agent, question answering agent and exam required by students

Agent is passed to students;

- (8) In order to adjust the students' learning suggestions for the next step, the student agent collects the students' answer results, evaluates the returned exam results, and the management agent receives the evaluation results of the exam agent, and then adjusts the students' learning suggestions for the next step through this evaluation.

The data layer is the third layer, where various data resources are stored. The specific content can be expressed as

$$S_t = \{t(x), c(x), f(x), i(x), q(x)\} \quad (4)$$

S_t Represents the composition of the data resource layer of the system, $t(x)$ Represents the mathematics teaching content library, $c(x)$ Indicates the question bank, $f(x)$ Represents the mathematics teaching strategy library, $i(x)$ Represents the student information base, $q(x)$ Question pool. It should be noted that the knowledge base is composed of specific mathematics curriculum knowledge taught by teachers. It plays the role of organizing materials needed for mathematics teaching, storing and managing all knowledge content required for courses in this mathematics teaching field. The test question database is composed of test questions. Its structure includes some basic attributes such as the body of the question, the specific answer to the question, the criteria for judging the question, the knowledge points involved in the question, the type of question, and the difficulty of the question. At the same time, the attributes of questions will serve as the basis of the examination agent, and according to the requirements of the examination, the questions with appropriate difficulty will be extracted from the question bank to form an examination paper. The difficulty of the questions also depends on the use.

The number of times varies, but the difficulty of the topic will decrease with the number of times it is used. The mathematics teaching strategy library mainly records various rules of software organization mathematics teaching and provides decision-making basis for the teacher agent. It records various rules such as the selection of

learning environment, the amount of tasks for this learning, the difficulty of learning, and whether to enter the review stage, enter the test link, etc. In order to fully reflect the autonomy of students, different students should have different mathematics teaching strategies and rules. Students' personal information can be expressed as

$$i(x) = \{name, sex, years, number\} \quad (5)$$

Among them, *name* Indicates the student's name information, *sex* Gender information indicated, *years* Indicates the age information of the student, *number* Represent the student ID information of the student, and put it into the student information database. At the same time, the student's learning situation is also recorded in the student information database. The specific information includes

$$k(x) = \{t(i), s(i), T(i), q(t), w(t)\} \quad (6)$$

Among them, $k(x)$ It represents the learning information of students, $t(i)$ Represents the learning time information, $s(i)$ Represent learning content information, $T(i)$ Indicates the number of learning times, $q(t)$ Indicates the current level information of students, $w(t)$ Indicates learning ability information.

3.2 Structure and Function Design of Each Agent

For the monitoring agent, this paper designs it to provide users with functions such as registration, login, and cancellation exit. When a user logs in, the legitimacy of the user is detected according to the user's registration information. If the user is legitimate, the corresponding teacher agent or student agent is generated. If it is a newly registered user, student users should fill in their own learning ability evaluation form, improve the registration information in the user's basic information data table, so that the system can put forward learning suggestions according to the user's cognitive ability. If a student wants to quit the mathematics teaching system after learning, save the student's learning record in the learning record agent and cancel the corresponding agent. The specific structure of the monitoring agent is shown in Fig. 3.

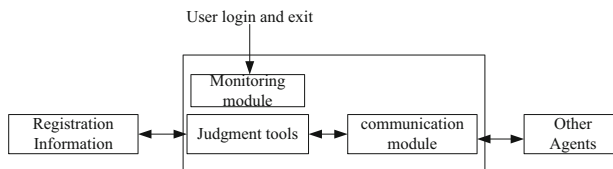


Fig. 3. Monitoring Agent Structure

Secondly, Student Agent Student Agent mainly communicates with other agents, among which communication with management agent is the most frequent. Its structure is shown in Fig. 4.

The functions of student agent include:

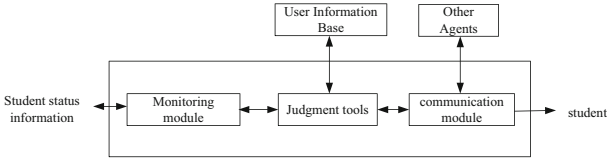


Fig. 4. Student Agent Structure

- (1) Send the user's basic information and request to the management agent through the identification provided by the user, and the management agent feeds back the corresponding mathematics teaching strategy to the student agent;
- (2) Assist students to interact with the system, effectively guide students' learning, master students' actual learning situation in the learning process according to the learning record agent, so as to better select the content learned;
- (3) According to the student's choice, the homework generated by the student agent through the homework agent, or the exercises or exams generated by the exam agent, will be displayed to the student for viewing;
- (4) Students submit the completed homework to the homework agent and obtain the evaluation results of the homework;
- (5) The exercises or exam questions that students have completed within the specified time are returned to the exam agent, and the corresponding answers, knowledge points involved in the questions and the evaluation of the exam are obtained through review;
- (6) But when encountering questions, you can establish a connection with the teacher agent, pass the questions to the teacher, and ask for answers;
- (7) Collect the students' learning conditions (such as the length of learning time, the results of practice exams, etc.) and hand them over to the management agent, who will give suggestions for the students to continue learning through these information;
- (8) When a student exits the system after learning, the student agent saves the student's learning record, and the corresponding student agent is also revoked.

The last is the design of teacher agent. When a teacher logs into the system, the teacher agent will be created by the monitoring agent. As the name implies, through the simulation of human teacher's wisdom, teacher agent should have rich knowledge level and mathematics teaching experience to control the mathematics teaching links in the system. It has the following main functions:

- (1) Check the learning situation of the students who choose this course, put forward guidance according to the students' learning requirements and actual situation, and send the advice to the management agent for mathematics teaching guidance and management of students, which is conducive to personalized mathematics teaching of students;
- (2) Assist teachers in editing, adding, deleting, modifying and updating mathematics teaching content, and help teachers formulate mathematics teaching strategies and rules;
- (3) Check students' current learning psychology, learning attitude, learning progress, learning questions, learning achievements and students' comprehensive learning

ability, make statistics of these information, and then give students' learning evaluation, as well as reasoning to solve various problems encountered in the mathematics teaching process, reorganize the mathematics teaching content, adjust the mathematics teaching methods and steps, so as to give the best mathematics teaching scheme;

- (4) Edit, modify, add, generate and publish assignments, exercises and test papers, and correct the assignments submitted by students, and update and maintain the exercise library and mathematics teaching content library in a timely manner;
- (5) Enter the question answering system, view the question answering database, participate in the student's question answering, answer the questions that cannot be answered in the question answering agent, and update the answer results to the question answering database;
- (6) Collect the information fed back by students and enrich the contents of student information database, knowledge database and mathematics teaching strategy database;
- (7) Communicate with other agents.

The last is the design of management Agent. The main function of management agent is management and communication. It controls the cooperation and scheduling among multiple agents. The structure of the management agent is shown in Fig. 5

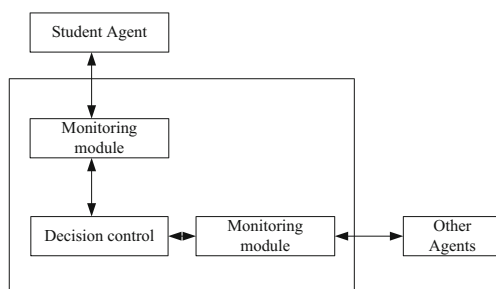


Fig. 5. Student Agent Structure

The main functions of the management agent are:

- (1) According to student information (provided by student agent), communicate with learning record agent to obtain the history of student learning;
- (2) According to the students' request, communicate with the mathematics teaching agent and provide the mathematics teaching content selected by the students to them;
- (3) According to the student's request and historical information, give corresponding suggestions for the student's learning content;
- (4) According to the student's request and the current learning situation of the student, communicate with the homework agent to provide students with difficult and appropriate homework; After students submit their homework, provide students with answers to the corresponding homework questions and the knowledge points involved;

- (5) According to the student’s request and referring to the student’s historical learning situation, communicate with the examination agent, and provide exercises or examination questions with appropriate difficulty to the student; After the students finish answering the questions and submit the test questions, provide the answers to the corresponding questions and the knowledge points involved to the students;
- (6) According to the student’s request, communicate with the question answering agent and give answers to the student’s questions;
- (7) According to the evaluation results of the examination agent, provide students with further learning suggestions;
- (8) According to the student learning information provided by the student agent, the corresponding learning suggestions are provided to students, so that students can learn more purposefully.

4 Test Experiment Analysis

4.1 Test Plan

According to the demand indicators of the web-based collaborative learning support system for mathematics courses, the system needs to meet the average concurrency of 1225 and the peak concurrency of 1326. To understand whether the concurrency performance of the server can meet the requirements, the test scheme developed in this paper is shown in Fig. 6.

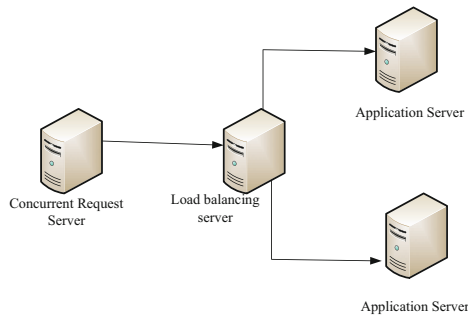


Fig. 6. Performance Test Scheme

First, run the load balancing server and business functions on different virtual machines, and then run a separate virtual machine as a concurrent request server to simulate user requests. Jmeter needs to be installed in the concurrent request server to simulate the concurrent request behavior of users. The configuration of each server is shown in Table 7.

In this test, the concurrent request server takes 100 users as the starting point, and adds 100 virtual users in turn.

The user records the CPU utilization response in the business function server through the built-in listener and plug-in of Jmeter Time and other parameters. Each concurrent request will be made many times. Finally, the average value measured many times will be recorded.

Table 7. Test Server Configuration

Server name	Number of cores	Memory
Concurrent request server	2	8.0
Load balancing server	2	8.0
application server	2	8.0
application server	2	8.0

4.2 Analysis of Test Results

Table 8 shows the server performance test results under different concurrent accesses. The average response time is a key indicator to measure the system response time.

Table 8. Server performance test results under different number of concurrent accesses

Concurrent requests	90%	95%	99%
100	10	12	28
200	20	27	33
300	51	56	65
400	76	100	126
500	326	420	630
600	659	705	931
700	922	1001	1170
800	1360	1432	1604
900	1514	1648	1885
1000	1624	1858	2225
1200	1834	2004	2259
1300	1835	2105	2351
1400	2131	2309	2460

According to the test results shown in Table 8, with the increasing number of concurrent accesses, the performance test results of the designed system show a stable development trend, with the corresponding average performance rising steadily, but the overall stability is within 2500. On this basis, the CPU usage of the system is compared with the increase of concurrent requests; As the number of concurrent requests increases, the average response time of the system changes. The mathematics teaching support system based on big data and the mathematics teaching support system based on B/S are set as the control group for the test, and the specific operation conditions of different systems under the same test environment are counted respectively. The test results are shown in Fig. 7 and Fig. 8.

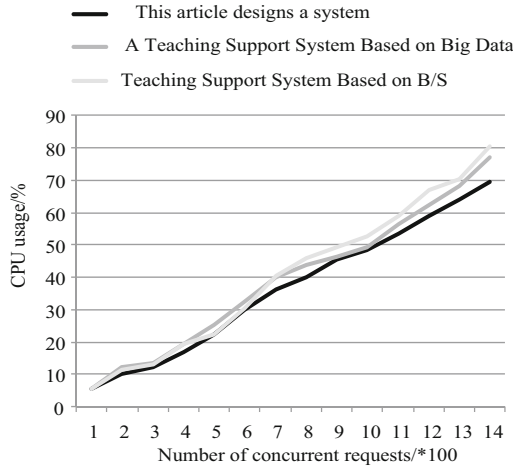


Fig. 7. Comparison Diagram of System CPU Usage

As can be seen from Fig. 7, as the number of concurrent requests of the system increases, the CPU utilization rate gradually increases. When the number of concurrent requests is 1400, the CPU utilization rate of the system designed in this paper is only 70.0%. At this time, the CPU utilization rate of the big data based mathematics teaching support system and the B/S based mathematics teaching support system reaches 82.01% and 76.44% respectively. In contrast, the running performance of the system designed in this paper is more stable. Not only that, but also from Table 9, the system did not reach the performance bottleneck when 1400 concurrent requests were made. When the number of concurrent users is 1300, the CPU utilization rate of the system designed in this paper is only 67.3%, and the probability of abnormal response requests is relatively low. Based on the above test results and analysis, it can be concluded that the system designed in this paper can support the concurrency of 1400 users and meet the requirements of 1226 Concurrency requirements during peak hours.

In Fig. 8, with the increase of the number of system users, the average response time of the three test systems gradually increases. When the number of users is 1400, the average response time of the system designed in this paper, the mathematics teaching support system based on big data and the mathematics teaching support system based on B/S are 466.3 ms, 512.40 ms and 535.20 ms respectively. The response rate of the system designed in this paper is significantly faster. Combined with the above test results and analysis, it can be concluded that the response time of the system in this paper can meet the response time index requirements in the actual application phase.

Analyze the changes in students' mathematical learning scores before and after the application of the system in this article. The analysis period is 3 months, and the changes in students' learning scores are shown in Table 9.

According to Table 9, after applying the system in this article, a total of 16 students' academic performance has been improved, while only 2 students' academic performance has decreased; Before the application of this system, only 5 students' academic performance improved, while 13 students' grades began to decline. The experiment

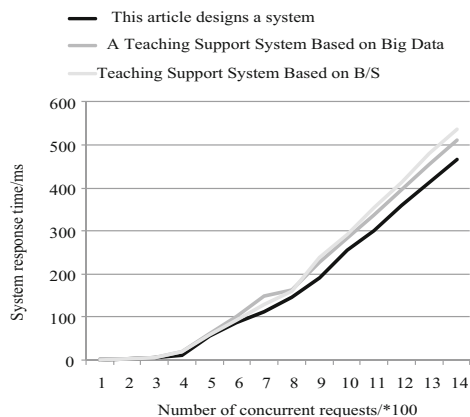


Fig. 8. Comparison Diagram of System Response Time

Table 9. Changes in student grades before and after the application of this system

Group	Number of people	Increase/decrease situation	Total variation	Average change per person
Before applying the system in this article	18	5 people increase by 11.4 points,	Reduce 28.4 points	Reduce 2.5 points
After applying the system in this article	18	13 people reduced by 5.8 points	Increase by 40.3 points	Increase by 2.7 points

proves that the application of this system can effectively improve students' math learning performance.

5 Conclusion

The rapid development of economy and society has changed people's production and living mode for a long time to a considerable extent. In education, the accelerating social rhythm makes the traditional face-to-face centralized mathematics teaching model unable to meet people's increasing learning needs. In recent years, with the rapid development of computer and multimedia technology, an information-based online mathematics teaching method relying on the Internet has gradually been accepted and recognized by people. At present, the popularity of the Internet in China is increasing day by day, and online mathematics teaching mode has gradually become a normal education mode that relies on and complements the traditional offline mathematics teaching mode with its advantages of fast transmission speed, wide coverage, and less impact from time and space. In this paper, the research on the multi-agent based network collaborative learning

support system for mathematics courses is proposed, which ensures that the running performance of the system can meet the objective requirements in the practical application stage.

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