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Research on the strategy of teaching Internet of Things communication with base group intelligence algorithm in enhancing teaching interactivity

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ABSTRACT

With the development of Internet of Things (IoT) technology, improving the interactivity of IoT communication teaching has become an important research content. This paper firstly constructs the IOT communication teaching system on the basis of service layer, network layer and teaching layer, through which the teaching information is ensured to be delivered timely and accurately. Secondly, the group intelligence algorithm teaching interactivity is optimized and designed to optimize the teaching environment, network, and teaching layer to get the optimized server resource allocation scheme to achieve the optimization of different levels in the teaching of Internet of Things communication. When the number of iterations reaches 20 and 45, the adaptability of this paper's algorithm is maintained between 100-10-1, and the optimization of the algorithm improves the student participation, the depth of understanding of knowledge, the accuracy of data, the speed of transmission, the efficiency of management, and the teaching effect by 28.6%, 41.7%, 4%, 100%, 18.8%, and 20%, respectively. In the delay analysis, when the number of terminals is 10, 20, and 30 respectively, the delay of the teaching system in this paper is the lowest among all the compared systems, which is 10ms, 40ms, and 230ms respectively.This study can lay the foundation for improving the quality and effect of IoT communication teaching and promote the cultivation of teaching interactivity between teachers and students.

Keywords: internet of things communication teaching, teaching interactivity, swarm intelligence algorithm, resource allocation, number of iterations

1. Introduction

With the continuous development of Internet of Things (IoT) technology, the teaching of IoT

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communication is increasingly widely used in the field of education [1]. However, in actual teaching, how to improve teaching interactivity and enhance students' learning experience and effect has become a problem to be solved. Traditional teaching methods often have limitations when facing the complex subject of IoT communication [2]. Problems such as irrational allocation of teaching resources, unstable network performance and single teaching mode may lead to low student participation and insufficient learning interest. Therefore, it is of great practical significance to introduce swarm intelligence algorithm to optimize the teaching environment of IoT communication [3]. The swarm intelligence algorithm can intelligently adjust the configuration of teaching resources according to the teaching needs, improve the stability and reliability of the network, and at the same time, enrich the teaching mode and increase the interactivity of teaching, so as to improve the learning effect and satisfaction of students [4].

With the globalization of communication, there are more and more researches on communication teaching, some researches in order to improve the quality of teaching in higher education institutions, design a 5G wireless communication based on the higher education institutions of three-dimensional classroom interactive teaching system, using three-layer Web structure to design the system architecture, in order to improve the independence of the system between the various functional modules, but also for each functional module is individually designed, so as to facilitate the each module individual upgrading and modification [5]. Some scholars believe that in the teaching of IoT communication, bringing relevant algorithms into the work of university education, the subject, object, content and effect all present new characteristics, and also improve the interaction between students in the classroom [6]. There are also scholars who mention in their research that in order to adapt to the needs of the rapid development of the Internet of Things and to maximize the effect of education. It is necessary for IoT communication educators to have big data thinking, change their working concepts, promote the rapid integration of old and new teaching modes, and optimize the construction of the talent team, so as to improve the interactivity in the communication teaching classroom [7]. There are also studies that propose a three-dimensional classroom interactive teaching system for higher education institutions based on B/S three-layer architecture, in order to meet the needs of teachers and students to use the system, the system needs to carry out complex online calculations, and the B/S three-layer architecture is used to build the system structure. MySQL database is used as the application database of the system to ensure the stable operation of the system, and interactive teaching is realized through interactive plug-ins [8]. Some scholars propose a three-dimensional classroom interactive teaching system for higher education institutions based on augmented reality technology, which introduces augmented reality technology into the research and development of the course teaching system. It improves the authenticity of simulation teaching through visual interaction, builds the awareness of graphic sense between view and form, strengthens students' comprehension, and completes the design of teaching system [9]. Another related research in the study of the proposed design of the classroom interactive teaching system, which covers the online teaching, answering, attendance, evaluation feedback and other functions. It consists of two modules, Zigbee wireless communication network and classroom interaction software, as a way to realize the monitoring of student interaction in communication teaching classroom [10].

In view of the traditional communication teaching classroom lack of interest leads to the lack of interaction between teachers and students as well as between students, so in order to improve classroom interactivity to promote the quality of teaching, the development and application of classroom interactive teaching system has become an inevitable trend. IOT communication teaching system covers three levels: service layer, network layer and teaching layer. ONS server, PML server, WEB server and EPC server are set up in the service layer to realize remote access and operation of the system through various servers. The network layer is responsible for the transmission of information in the service layer, which is the bridge connecting the layers and ensures the timely and accurate transmission of teaching information. The teaching layer, as the communication information collection layer in the Internet of Things, is the basic link of practical teaching, and the system starts RFID read-write in this layer to transmit read signals to the electronic tags and decode the tag information to provide real-time information for teaching. Particle swarm optimization algorithm is used for optimization, including the optimization of teaching environment, network layer and teaching layer. The algorithm updates the particle speed and position to achieve the optimal allocation of resources in the teaching environment, adjusts the particle position to optimize the network performance and student participation, and optimizes the core modules to improve the quality and efficiency of teaching, thus enhancing the interactivity of teaching.

2. Internet of Things Communication Teaching System

IoT has a high-performance streaming media transmission environment that can provide students with smooth video resources to facilitate intuitive learning. The realization environment that integrates video transmission, mixed reality and virtual reality technology creates an immersive learning experience that makes students feel as if they are in a real scene. Figure 1 shows the architecture of the IoT communication teaching system, which is divided into three layers, service layer, network layer, and teaching layer [11-12]. The application service environment contains subsystems such as virtual assisted teaching, video teaching, digital display and interactive virtualization to enrich teaching means and resources. The teaching environment is constructed through radio frequency identification, infrared sensor, global positioning system, laser scanner and other information sensing equipment, according to the agreed agreement to connect the logistics items with the Internet, to realize the information exchange and communication, and to reach the intelligent identification, positioning, tracking, monitoring and management of teaching. The details are as follows:

1) The service layer consists of various servers for IoT communication teaching system, which consists of ONS resolution service system, referred to as ONS server, PML physical markup language server, and EPC network system [13-14].

2) The network layer consists of the Internet, wireless devices and Internet devices, which is responsible for the service layer information transmission, and is a bridge connecting all levels to ensure the timely and accurate transmission of teaching information.

3) Teaching layer as the Internet of Things RFID communication information collection layer, is the practice of teaching the basic link, there are RFID read-write, RFID communication tags and other facilities and related management tools, the system in this layer to start the RFID read-write to the electronic tags to transmit read signals and decode the tag information, to provide real-time information for teaching [15].

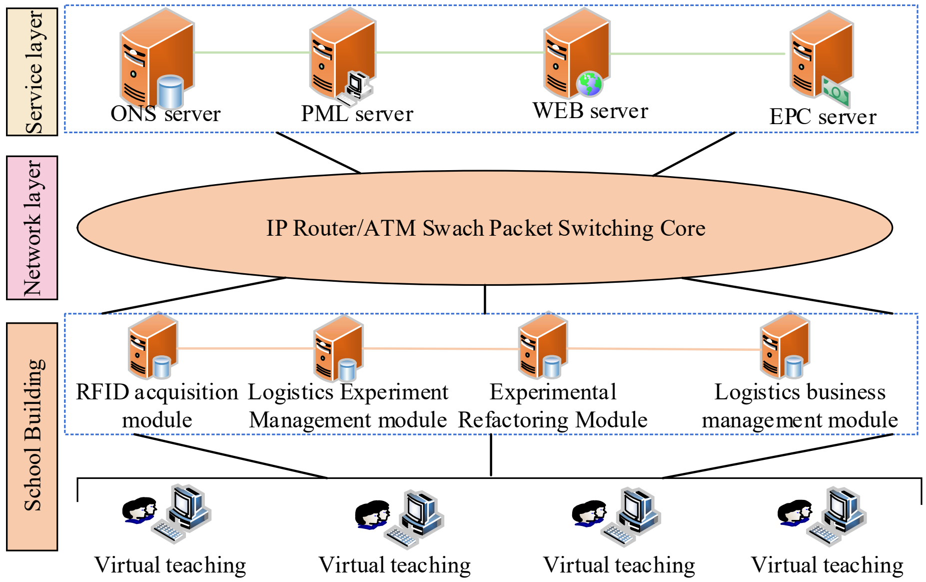

Fig. 1. IoT communication teaching system architecture

The communication teaching environment constructed in the IoT environment shows its unique characteristics of shareability, immersion and interactivity, which brings a brand new experience for IoT communication teaching. Shareability means that this teaching environment makes full use of network technology to build a visualized, three-dimensional virtual learning platform. On this platform, all kinds of 3D models representing IoT communication devices and business processes are carefully designed, and students can access and operate them remotely only through their personal terminals to conduct virtual experiments. This kind of resource sharing effectively avoids the repeated acquisition and waste of physical equipment in traditional teaching, and also breaks the limitations of geography and time, making learning more flexible and efficient [16]. Immersion is to provide students with a deeper understanding of the complexity and diversity of IoT communications, the teaching environment provides highly simulated virtual scenes. These scenes are in the form of 3D stereograms, which vividly demonstrate the learning methods and practical application scenarios of IoT communication, such as data transmission and device interconnection. Students seem to be in the real world of IoT and are able to visualize the charm and power of communication technology, thus enhancing their immersion and interest in learning. Interactivity is greatly enhanced in the IoT communication teaching environment. Students are not only free to observe virtual IoT devices and business processes from different perspectives, but also to interact with the environment in real time. The interactive interface allows students to easily perform various operations, such as virtual labs, simulation software, and instructional videos. These operations allow students to master the core skills of IoT communication in practice and improve their ability to solve real-world problems [17-18].

3. Swarm Intelligence Algorithms to Optimize the Design of Teaching Interactivity

3.1. Optimization of the teaching environment

The particle swarm optimization algorithm PSO in swarm intelligence algorithms has advantages such as fast computation speed to optimize the allocation of various components in the teaching environment in order to improve teaching interactivity and efficiency. When optimizing the allocation of resources such as ONS servers and PML servers in the service layer, an optimization formula can be constructed to ensure efficient and stable data transmission and processing in the teaching and learning process, so as to reduce latency and packet loss, and improve the real-time nature of teaching and learning interaction [19]. The following is an optimization model framework:

The objective function is set to be E, and the delay time, packet loss rate and real-time teaching interaction are considered together. The formula is:

$$E = w_1 \times T + w_2 \times P + w_3 \times (1 - I) \tag{1}$$

where, T represents the delay time of data transmission, P represents the packet loss rate, and I represents the real-time index of teaching interaction. w_1、w_2、w_3 is the weight coefficient, and $w_1+w_2+w_3=1$, the weights are adjusted according to the actual demand to determine the importance of each factor in the objective function.

Each particle represents a server resource allocation scheme, which can be represented by a vector, and each element of the vector corresponds to a server resource allocation ratio. A set of particles is randomly generated as the initial population. For each particle, its corresponding resource allocation scheme is substituted into the objective function E and the fitness value is calculated. The smaller the fitness value, the better it represents that resource allocation scheme. In the particle swarm optimization algorithm applied to the server resource allocation problem, the speed update is very important. The velocity update determines how the particle adjusts its own moving speed in each iteration, which can better understand the space and converge to the optimal server resource allocation scheme.The following is the formula for updating the velocity and position of the particles, and the velocity update formula is:

$$v_{id}^{k+1} = w \times v_{id}^{k} + c_1 \times r_1 \times \left(pbest_{id} - x_{id}^{k} \right) + c_2 \times r_2 \times \left(gbest_d - x_{id}^{k} \right) \tag{2}$$

In the particle swarm optimization algorithm, each particle represents a server resource allocation scheme, and each element of the position vector X_{id} corresponds to a server resource allocation ratio [20]. In each iteration, the positions of the particles need to be updated to explore a more optimal solution space. The position update formula is as follows:

$$x_{id}^{k+1} = x_{id}^{k} + v_{id}^{k+1} \tag{3}$$

where x_{id}^{k} represents the position of particle i at the krd iteration, i.e. the current resource allocation scheme. v_{id}^{k+1} is the velocity of particle i at the $k+1$th iteration, which determines the direction and magnitude of the particle position change.

Repeat the above steps until the termination condition is satisfied, the maximum number of iterations is reached or the fitness value is less than a certain threshold, and the final global optimal position obtained is the optimized server resource allocation scheme [21-22].

3.2. Network Layer Optimization

Particle Swarm Optimization Algorithm as a population intelligence based optimization algorithm, each particle represents a potential solution to the problem. The particle location representation covers multiple parameters such as network layer, IP router, ATM switching, packet and immersibility related parameters.In the network layer, the particle optimization algorithm is used to optimize the IP router/ATM switching packet switching core. The performance optimization of the packet switching core in the network is transformed into a function optimization problem. The objective function is set to F and the formula is as follows:

$$F = \frac{1}{T} + \alpha \times L + \beta \times P + \gamma \times U \tag{4}$$

where, T is the objective function synthesizing the delay time, T is the packet loss rate, P is the student's engagement in the virtual scenario, U is the depth of understanding of the knowledge, and α、β、Y is the weighting factor.

The speed update formula is crucial when optimizing the network layer IP router/ATM switch packet switching core. It determines the speed at which the particles move in the search space and guides the particles to converge to a more optimal solution. The velocity update formula is:

$$V_{id}^{k+1} = wV_{id}^{k} + c_1 r_1 \left(P_{id}^{k} - X_{id}^{k}\right) + c_2 r_2 \left(G_{id}^{k} - X_{id}^{k}\right) \tag{5}$$

where V_{id}^{k+1} represents the velocity of particle i in the dth dimension at the $k+1$rd iteration, and G_{id}^{k} is the value of the global optimal position of the whole particle swarm in the dth dimension.

The positions of the particles represent various parameter sets, and optimization is achieved by continuously adjusting the particle positions to find the optimal parameter combinations. The position update formula is:

$$X_{id}^{k+1} = X_{id}^{k} + V_{id}^{k+1} \tag{6}$$

3.3. Teaching layer optimization

In the optimization of the teaching layer, the particle optimization algorithm is still used. The algorithm can comprehensively optimize multiple core modules of the teaching layer to improve the quality and efficiency of teaching. The key performance indicators and optimization objectives of each core module should be clarified. For RFID collection module, focus on data accuracy and transmission speed. The experimental management module focuses on management efficiency and resource allocation rationality, the experimental reconstruction module emphasizes the degree of innovation and reconstruction speed, the virtual teaching management module highlights convenience and functional integrity, and the virtual communication teaching pays attention to teaching effect and interactivity. The comprehensive objective function is set as J, and the formula is as follows:

$$J = w_1 R(x_1) + w_2 E(x_2) + w_3 I(x_3) + w_4 B(x_4) + w_5 V(x_5) \tag{7}$$

In the formula, the degree of importance attached to different modules can be adjusted according to the actual teaching needs, and $R(x_1)$、$E(x_2)$、$I(x_3)$、$B(x_4)$、$V(x_5)$ corresponds to the assessment index of each module respectively.

Particle optimization algorithm is used for optimization. The position of the particle indicates the parameter combination of each module, and the speed and position of the particle are updated through continuous iteration to find the parameter combination that optimizes the objective function. The velocity update formula is:

$$V_{id}^{k+1} = wV_{id}^{k} + c_1 r_1 \left(P_{id}^{k} - X_{id}^{k}\right) + c_2 r_2 \left(G_{id}^{k} - X_{id}^{k}\right) \tag{8}$$

where k is the current iteration number and d indicates that the dimension corresponds to different modules, such as RFID acquisition module, experiment management module, etc.

The position update formula is:

$$Y_{id}^{k+1} = Y_{id}^{k} + U_{id}^{k+1} \tag{9}$$

where Y_{id}^{k+1} represents the position of particle i in the dth dimension at the $k+1$rd iteration, Y_{id}^{k} is the position of particle i in the dth dimension at the 2nd iteration, and U_{id}^{k+1} represents the velocity of particle i in the dth dimension at the $k+1$th iteration.

The optimization algorithms all use the particle swarm optimization algorithm to optimize the different levels of teaching IoT communication by defining the objective function, particle representation, velocity update and position update formulas in order to improve the teaching interactivity, efficiency and quality.

4. Teaching Interactivity Enhancement Validation

4.1. Adaptation analysis

In order to verify the effectiveness of particle swarm optimization algorithm applied in the teaching designed in this paper, the corresponding simulation analysis is carried out. Sensors are set up in the area, and the sensing distance of the sensors is required to be 12 m. Two monitoring points are set up, and the distance between the monitoring points is regarded as the communication distance, which is 24 m. The energy consumed for the data transmission between the two monitoring points is 40 nJ/bit, and the energy required for the reception of the data between the monitoring points is 25 J/bit, and the optimization simulation program is prepared by using MATLAB software Experimental comparisons are carried out and the adaptation simulation results are shown in Fig. 2.

When the number of iterations is 0, the fitness of the two algorithms is equal, with the increase of the number of iterations, the fitness of the two algorithms are beginning to show a downward trend; when the number of iterations is 10, the fitness of the traditional timing method is between 10^{-1}-10^{0}, and the fitness of the particle swarm optimization algorithm of this paper at this time is between 10^{0}-10^{1}. When the number of iterations reaches 20, the fitness of the traditional timing algorithm is between 10^{-2}-10^{-1} and closer to 10^{-1}, while the particle swarm optimization algorithm's fitness is between 10^{0}-10^{-1} at this point. This difference in data suggests that at earlier iterations, the particle swarm optimization algorithm is already able to find better solutions and exhibits faster convergence. As the number of iterations increases further, this advantage becomes even more pronounced. When the number of iterations reaches 45, the fitness of the traditional timing algorithm is between 10^{-2}-10^{-1} and closer to 10^{-2}, while the fitness of the particle swarm optimization algorithm still remains between 10^{0}-10^{-1} but closer to 10^{-1}. This means that for the same number of iterations, the particle swarm optimization algorithm is able to find lower and better fitness values, which significantly improves the IoT communication Reliability of teaching. From the iteration process, the curve of the particle swarm optimization algorithm is smooth and continuously decreasing without obvious fluctuation or stagnation, which indicates that its stability and consistency are ideal, and it can effectively avoid falling into the local optimal solution or converging prematurely. This stability can provide a more reliable teaching environment and enhance teaching interactivity, such as reducing interruptions or delays caused by technical problems and enabling students to participate in interactions more smoothly.

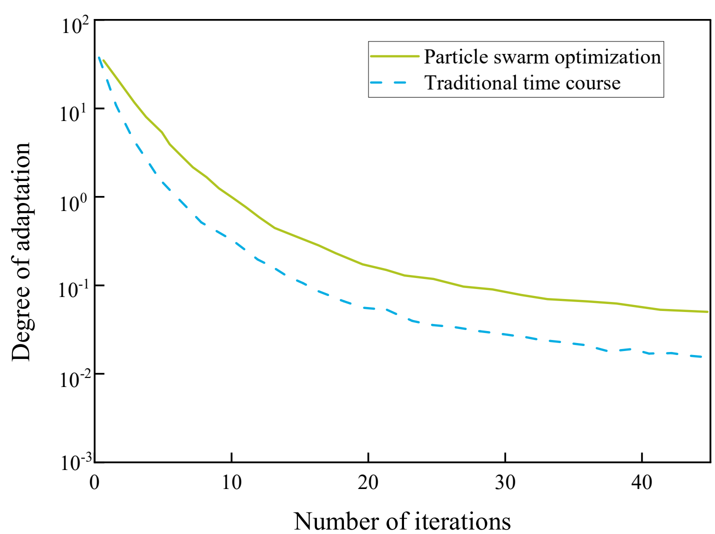

Fig. 2. Adaptation simulation results

4.2. Comparison of the overall optimization of teaching IoT communication

In order to assess the effectiveness of the optimization measures of the swarm intelligence algorithm in improving the teaching of IoT communication, the indicators of the teaching layer of the teaching system and its projects were monitored and analyzed. The optimization is only for the teaching layer, and the effectiveness of the optimization measures can be clearly seen by comparing the index data before and after the optimization. Table 1 shows the performance of IoT communication teaching before and after optimization. After the optimization of particle swarm optimization algorithm, the performance related to the teaching of IoT communication has been greatly optimized. In the teaching layer, student engagement increased from 70% to 90%, which is a 28.6% increase in engagement. Students' depth of understanding increased from 60% to 85%, with a 41.7% increase in depth of understanding.The data accuracy of the RFID collection module increased from 95% to 99%, with a 4% increase in data accuracy.The RFID data transmission speed increased from 100kbps to 200kbps, with a 100% increase in transmission speed. The efficiency of experiment management module is improved from 80% to 95%, and the management efficiency is improved by 18.8%. The teaching effectiveness of virtual communication increased from 75% to 90%, a 20% increase in teaching effectiveness. These data show that the optimization of the teaching layer not only effectively improves student interaction in the virtual classroom, but also significantly improves the accuracy of data collection, data transmission speed, management efficiency of the teaching layer, and the overall teaching effect.

Table 1. Teaching performance of IoT communication before and after optimization

Optimization Hierarchy	Optimization Project	Before Optimization	Post-Optimization Metrics	Optimization effect
Teaching layer	Student engagement	70%	90%	28.6% increase in engagement
	Depth of student understanding	60%	85%	Depth of understanding increased by 41.7%
	Data accuracy of RFID collection module	95%	99%	4% increase in data accuracy
	RFID data transmission speed	100kbps	200kbps	100% increase in transmission speed
	Efficiency of experiment management module	80%	95%	18.8% increase in management efficiency
	Virtual communication teaching effect	75%	90%	20% increase in teaching effectiveness

4.3. Analysis of Teaching Interactivity

In order to better verify that this artifacts networking communication teaching system can significantly enhance the enthusiasm of students in the classroom, a school was selected to participate in the experiment with 100 students in two classes with similar learning, 50 students were assigned to the control group, 50 students were assigned to the experimental group, and the classroom of the students in the control group will adopt the teaching mode under the traditional teaching system of the temporal algorithm, while the experimental group adopts the teaching mode under the teaching system of the particle swarm optimization algorithm of this paper. Table 2 shows the students' classroom interactivity under different teaching systems. In terms of students' classroom participation, the number of questions asked by students in the experimental group is 50% higher than that in the control group, and in terms of group discussion participation, the number of active participants in the experimental group is 20% higher than that in the reference group. In terms of students' interactive participation, the number of active participants in the experimental group is 25% higher than that in the control group, indicating that the teaching mode of the experimental group can better promote students' participation in classroom interaction and improve the effect of cooperative learning. In terms of teaching efficiency, the completion time of the interactive exercises was 16.7% shorter in the experimental group than in the control group. In terms of the correct rate, the accuracy rate of students' answers to questions and the correct rate of interactive exercises in the experimental group is 10% higher than that of the control group, indicating that the teaching mode of the experimental group has a positive effect on improving students' learning efficiency and accuracy rate.

Table 2. Student classroom interactivity under different teaching systems

Pilot program	Control group (50 people)	Experimental group (50 people)
Number of questions asked by students (average per session)	20 times	30 times
Accuracy of students' answers to questions (%)	75%	85%
Participation in group discussions (percentage of active participants)	50%	70% of the total number of repetitions
Completion time of interactive exercises (average time)	12 minutes	10 minutes
Correct rate of interactive exercises (%)	80% 50%	90% of the total number of repetitions
Assessment of the quality of classroom presentations (equal average score)	70 minutes	85 minutes
Participation in student interactions (% of active participants)	40%	65%
Diversity of classroom interactions (number of types)	3 types	5 types
Timeliness and effectiveness of instructor feedback (average score)	70 points	85 points

4.4. Delay analysis

In order to verify that the IoT communication teaching system designed in this paper has good performance in terms of system operation latency, here the latency will be compared on the basis of the teaching system based on the teaching system under the traditional timing algorithm, the teaching system under the particle swarm optimization algorithm, the teaching system based on joint deep learning, and the teaching system based on fuzzy recognition, and the system operation latency is shown in Figure 3. As the number of terminals rises, the latency of each system also increases significantly. When the number of terminals is 10, the latency of the deep learning teaching system reaches 420ms, the latency of the teaching system under the traditional timing algorithm is 250ms, the latency of the teaching system under the fuzzy recognition teaching system is 158ms and the latency of the teaching system under the particle swarm optimization algorithm of this paper is 10ms. When the number of terminals is 20, the latency of the teaching system under the deep learning teaching system remains the highest, the latency of the teaching system under the fuzzy recognition teaching system is 158ms and the latency of the teaching system under the particle swarm optimization algorithm of this paper is 10ms. When the number of terminals is 30, the deep learning teaching system, the teaching system under the traditional timing algorithm, the fuzzy recognition teaching system is better, and the teaching system under the particle swarm optimization algorithm of this paper has the lowest latency, with the latency of 910ms, 580ms, 390ms, and 40ms, respectively.The teaching system under the deep learning algorithm, the teaching system under the traditional timing algorithm, the teaching system under the fuzzy recognition teaching system are kept in the state when the number of terminals is 30, teaching system under the particle swarm optimization algorithm in this paper, the latency is 1320ms, 1100ms, 670ms, 230ms respectively, so the system designed in this paper can effectively reduce the latency.

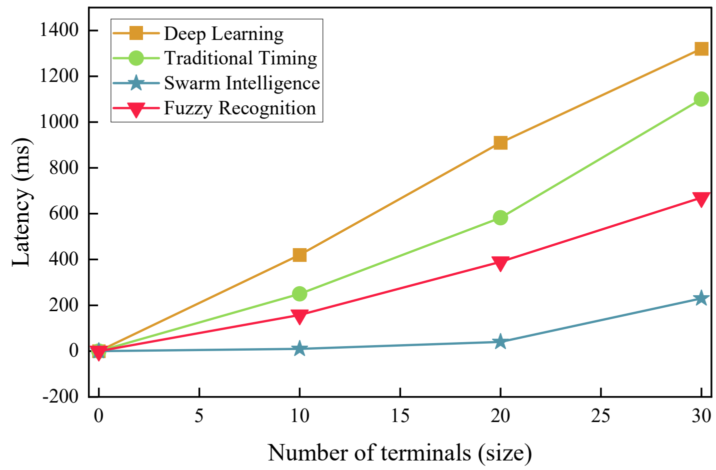

Fig. 3. System operation latency

5. Conclusion

In this paper, in order to verify the effectiveness of the teaching system under the designed particle swarm optimization algorithm, experiments were conducted in four aspects, namely, adaptability analysis, comparative analysis of the overall optimization of IoT communication teaching, analysis of teaching interactivity, and analysis of latency. The conclusions are as follows:

1) When the number of iterations reaches 20 times, the adaptability of the particle swarm optimization algorithm is between 100-10-1. When the number of iterations reaches 45 times, the adaptability of the particle swarm optimization algorithm is still maintained between 100-10-1, and this paper's algorithm has obvious advantages in convergence speed and stability.

2) In the overall optimization comparison analysis, student participation, depth of understanding of knowledge, data accuracy, transmission speed, management efficiency, and teaching effect are improved by 28.6%, 41.7%, 4%, 100%, 18.8%, and 20% respectively after the particle swarm optimization algorithm, so there is a significant improvement in the performance of this paper's teaching system after optimization. In the analysis of teaching interactivity, the students in the experimental group have been significantly improved both in terms of classroom interactivity starting from the accuracy rate. The number of questions asked, the number of active participants, the accuracy rate of answering questions, and the correct rate of interactive exercises are 50%, 20%, 10%, and 10% higher than that of the control group, respectively, and the time taken by the experimental group of students to complete the interactive exercises is 16.7% shorter than that of the control group, so that the teaching mode has a positive effect on the improvement of students' learning efficiency and accuracy rate.

3) In the delay analysis, when the number of terminals is 10, 20 and 30 respectively, the delay of the teaching system in this paper is the lowest among all the comparative systems, which is 10ms, 40ms and 230ms respectively, and the system designed in this paper can effectively reduce the operation delay and improve the adaptability of resources.

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References

[1] Eli, T. (2021). Studentsperspectives on the use of innovative and interactive teaching methods at the

University of Nouakchott Al Aasriya, Mauritania: English department as a csase study. *International Journal of Technology, Innovation and Management (IJTIM)*, *1*(2), 90-104.

[2] Tuma, F. (2021). The use of educational technology for interactive teaching in lectures. *Annals of Medicine and Surgery*, *62*, 231-235.

[3] Agustina, L., & Setiawan, R. (2020). Fostering a natural atmosphere; improving students' communication skill in a business meeting. *Journal of Languages and Language Teaching*, *8*(3), 307-314.

[4] Tsai, M. N., Liao, Y. F., Chang, Y. L., & Chen, H. C. (2020). A brainstorming flipped classroom approach for improving students' learning performance, motivation, teacher-student interaction and creativity in a civics education class. *Thinking Skills and Creativity*, *38*, 100747.

[5] Huang, F. (2022). Multimedia Wireless-Network-Based Model for Smart Interactive Translation Teaching. *Wireless Communications and Mobile Computing*, *2022*(1), 1940432.

[6] Putri, D. P., Ferdianto, F., & Fauji, S. H. (2020). Designing a Digital Teaching Module Based on Mathematical Communication in Relation and Function. *Journal on Mathematics Education*, *11*(2), 223-236.

[7] Lee, J., Kim, H., Kim, K. H., Jung, D., Jowsey, T., & Webster, C. S. (2020). Effective virtual patient simulators for medical communication training: a systematic review. *Medical education*, *54*(9), 786-795.

[8] Aslan, A. (2021). Problem-based learning in live online classes: Learning achievement, problem-solving skill, communication skill, and interaction. *Computers & Education*, *171*, 104237.

[9] Zhang, J. H., Zou, L. C., Miao, J. J., Zhang, Y. X., Hwang, G. J., & Zhu, Y. (2020). An individualized intervention approach to improving university students' learning performance and interactive behaviors in a blended learning environment. *Interactive Learning Environments*, *28*(2), 231-245.

[10] Owens, A. D., & Hite, R. L. (2022). Enhancing student communication competencies in STEM using virtual global collaboration project based learning. *Research in Science & Technological Education*, *40*(1), 76-102.

[11] Molina Roldán, S., Marauri, J., Aubert, A., & Flecha, R. (2021). How inclusive interactive learning environments benefit students without special needs. *Frontiers in Psychology*, *12*, 661427.

[12] Moreno-Guerrero, A. J., Rodríguez-Jiménez, C., Gómez-García, G., & Ramos Navas-Parejo, M. (2020). Educational innovation in higher education: Use of role playing and educational video in future teachers' training. *Sustainability*, *12*(6), 2558.

[13] Nahar, S. (2022). Improving Students' Collaboration Thinking Skill under the Implementation of the Quantum Teaching Model. *International Journal of Instruction*, *15*(3), 451-464.

[14] Munna, A. S., & Kalam, M. A. (2021). Teaching and learning process to enhance teaching effectiveness: a literature review. *International Journal of Humanities and Innovation (IJHI)*, *4*(1), 1-4.

[15] Asad, M. M., Hussain, N., Wadho, M., Khand, Z. H., & Churi, P. P. (2021). Integration of e-learning technologies for interactive teaching and learning process: an empirical study on higher education institutes of Pakistan. *Journal of Applied Research in Higher Education*, *13*(3), 649-663.

[16] Tai, T. Y., & Chen, H. H. J. (2023). The impact of Google Assistant on adolescent EFL learners' willingness to communicate. *Interactive Learning Environments*, *31*(3), 1485-1502.

[17] Jurakovic, L., Tatkovic, S., & Radulovic, P. (2022). Students' Attitudes towards Online Teaching and Communication during the Coronavirus Pandemic. *Journal of Learning for Development*, *9*(2), 253-266.

[18] Hasanah, H., & Malik, M. N. (2020). Blended learning in improving students' critical thinking and communication skills at University. *Cypriot Journal of Educational Sciences*, *15*(5), 1295-1306.

[19] Siddig, B. (2020). Social media in teaching of languages. *International Journal of Emerging Technologies in Learning (iJET)*, *15*(12), 72-80.

[20] Tarigan, E. F. (2022). Implementation of Think Pair Share (TPS) Learning Strategies to Improve Students' Mathematical Communication Skills on Integer Materials in Class VII SMP Negeri 1 Tigabinanga 2014/2015 Academic Year. *Indonesian Journal of Education and Mathematical Science*, *3*(1), 12-17.

[21] Yao, J., Rao, J., Jiang, T., & Xiong, C. (2020). What role should teachers play in online teaching during the COVID-19 pandemic? Evidence from China. *Sci Insigt Edu Front*, *5*(2), 517-524.

[22] Bulturbayevich, M. B., Rahmat, A., & Murodullayevich, M. N. (2021). Improving Teacher-Student Collaboration And Educational Effectiveness By Overcoming Learning Challenges. *Aksara: Jurnal Ilmu Pendidikan Nonformal*, *7*(1), 153-160.