Mobile Information Systems

Mobile Edge Computing in Citizen Science

Lead Guest Editor: Zhiyong Yu
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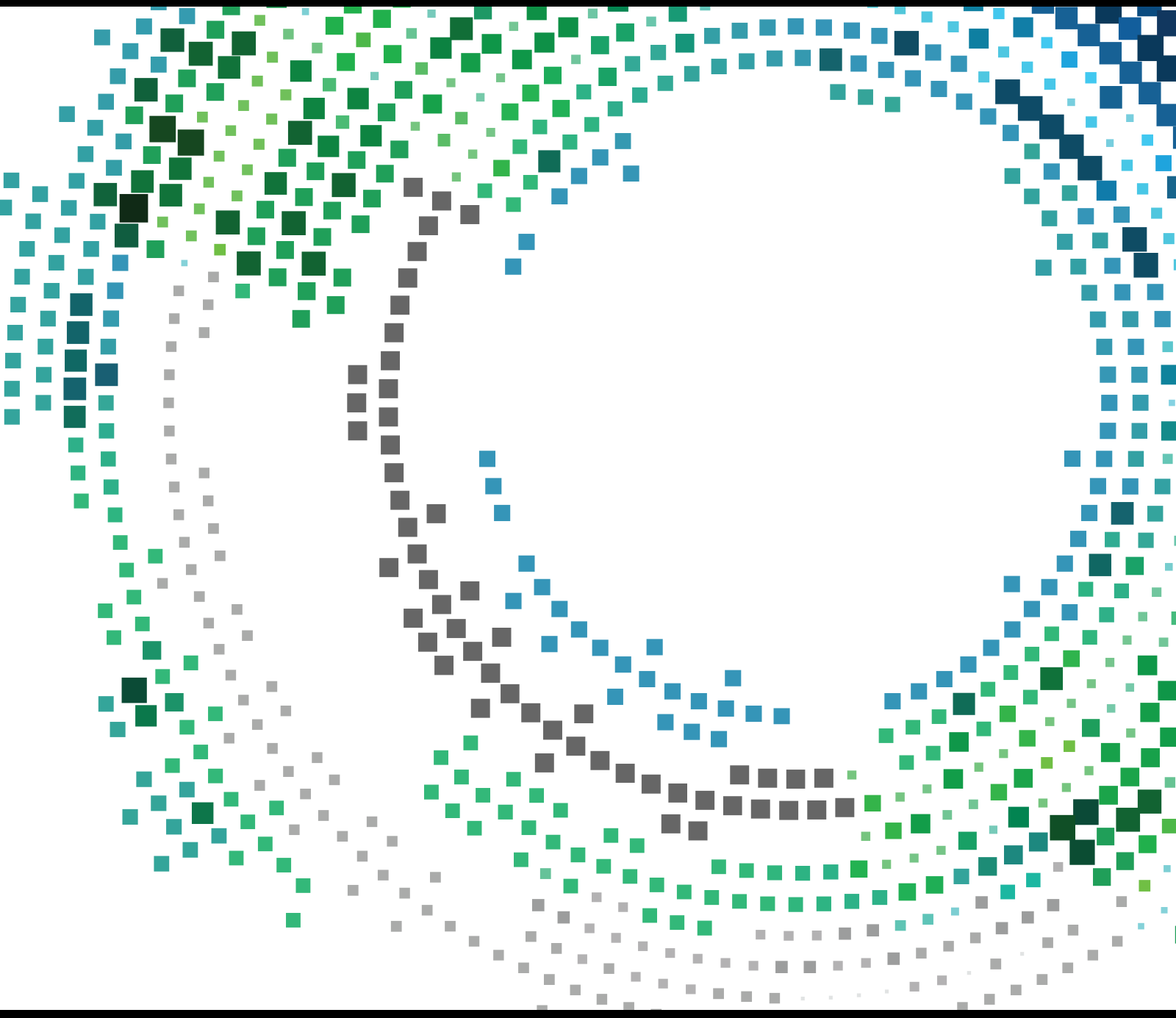

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Hindawi
Mobile Information Systems
Volume 2021, Article ID 7716654, 17 pages
https://doi.org/10.1155/2021/7716654

Research Article

Computation Offloading Optimization in Mobile Edge Computing Based on HIBSA

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Received 6 August 2021; Revised 3 October 2021; Accepted 13 October 2021; Published 5 November 2021

Academic Editor: Zhiyong Yu

Multiaccess edge computation (MEC) is a hotspot in 5G network. The problem of task offloading is one of the core problems in MEC. In this paper, a novel computation offloading model which partitions tasks into subtasksis proposed. This model takes communication and computing resources, energy consumption of intelligent mobile devices, and weight of tasks into account. We then transform the model into a multiobjective optimization problem based on Pareto that balances the task weight and time efficiency of the offloaded tasks. In addition, an algorithm based on hybrid immune and bat scheduling algorithm (HIBSA) is further designed to tackle the proposed multiobjective optimization problem. The experimental results show that HIBSA can meet the requirements of both the task execution deadline and the weight of the offloaded tasks.

1. Introduction

With the rapid development of the Internet of Things (IoT), intelligent mobile devices (IMDs) have become indispensable tools in people's daily life, and their functions have become more and more powerful, which can meet people's needs in social, shopping, travel, entertainment, and so on. Due to the physical size constraint, mobile devices are usually resource-constrained and have a limited power supply. However, most of the computation-intensive services, such as image processing or video-based applications, need high processing power and have high resources consumption [1, 2]. Compute-intensive tasks cannot be completed in time or may even be blocked if they are only processed locally [3]. Hence, how to solve the contradiction between the limited resources of mobile terminals and the high resources requirement of compute-intensive services has become one of the main problems to be solved [4].

Nowadays, multiaccess edge computation (MEC) [5] has been a promising paradigm to resolve the abovementioned problem [6, 7]. In MEC, an edge site/server is a microdata center, which is deployed attached to a small base station (SBS). By moving computing storage and service capabilities to the network edge, MEC can provide high reliability, high bandwidth, and low-latency computing services for mobile devices. Since mobile terminals can then offload tasks to the nearby edge computing servers with rich computing resources, the problem of resource limitation of IMDs can be resolved to some extent.

Obviously, when multiple IMDs upload tasks at the same time, they will inevitably compete with each other for both communicational and computing resources [8]. Unreasonable resource allocation can result in a low data transmission rate and high delay. Therefore, the designation of the task scheduling scheme has an important influence on the performance of the MEC system. So far, many researchers have focused on the computation offloading scheduling problem. However, most of these studies have performance limitations, which can be explained from the following aspects. Firstly, some researches allocate tasks to only one edge server. However, since the density of SBSs is high [9, 10] in the future and the signal coverages of the SBSs often overlap with each other in real-world scenarios, there are multiple options when unloading tasks. In addition, application partitioning and repartitioning have been studied in depth in mobile cloud computing and distributed systems [11, 12], which can be used in the MEC system. Following these two ideas, assigning tasks to multiple edge

servers is more reasonable. Secondly, some works [13] ignored the energy consumption of the IMDs. In fact, the energy consumption of mobile device must be considered because they usually cannot be recharged timely. Thirdly, most studies did not consider the weight of offloading tasks. However, those tasks that are important or have a long waiting time in the scheduling queue should be scheduled in priority for fairness. Finally, some studies have not jointly considered the allocation of both the communication and computing resources. Compared with the prior works, the contributions of our paper are as follows:

(i) The proposed task offloading model takes communication and computing resources, energy consumption of the IMD, and weight of tasks into account.

(ii) We consider the scenario that the mobile device can generate multiple tasks at the same time, which is more realistic compared with most related works. Moreover, we partition compute-incentive tasks into subtasks and then offload them to multiple edge servers for parallel computing. Compared to offloading a single task to an edge server, tasks can be executed in a more efficient way.

(iii) A novel multiobjective task scheduling algorithm is designed, which combines the advantages of both the bat algorithm and the immune algorithm to improve the reliability of task offloading while reducing the task completion time.

(iv) Extensive simulations have been conducted, and the results show that the proposed algorithm can effectively shorten the task execution time and has higher reliability compared with conventional algorithms.

The rest of this paper is organized as follows. Section 2 presents related works. Section 3 describes the system model and the problem formulation. In Section 4, we transform the offloading decision problem into a multiobjective optimization problem based on Pareto and then design a multiobjective task scheduling algorithm based on hybrid immune and bat scheduling algorithm (HIBSA). Section 5 gives the experimental comparisons of HIBSA with other algorithms, which validate the superior performance of HIBSA. Finally, we make the conclusion in Section 6.

2. Related Work

Task offloading refers to the process of allocating tasks to edge servers with sufficient resources according to some offloading policies. These policies determine both the efficiency and the achievable computation performance of the MEC. Task offloading is also called computing migration or computing offloading [14]. By delivering compute-incentive tasks such as face recognition and video optimization to MEC servers, high task quality of service (QoS) is achieved. In the last few years, task offloading problems have attracted great interest of researchers. For instance, Wu et al. [10] proposed an offloading algorithm based on support vector machine (SVM). The proposed algorithm firstly segments a task into several subtasks by using a weight allocation method. Then, each subtask is determined to be offloaded or executed locally. In [11], Mao et al. developed an online joint radio and computational resource management algorithm for a multiuser MEC system, with the objective of minimizing the long-term average weighted sum power consumption of the mobile devices and the MEC server, subject to a task buffer stability constraint. In literature [12], the authors proposed an efficient computation offloading algorithm by jointly optimizing user association and computation offloading where computation resource allocation and transmission power allocation are also considered. Also, the authors in work [13] proposed a novel offloading system to design robust offloading decisions for mobile services. This system considers the dependency relations among component services and aims to optimize task execution time and energy consumption of mobile devices. These abovementioned researches focus on the computation offloading problem in the single-server MEC system.

On the other hand, many researchers have devoted their efforts to task offloading problems in multiuser and multiserver MEC systems. For example, in [15], a cross-edge computation offloading framework for compute-incentive applications was proposed. The transmission cost, task execution cost, coordination cost, as well as penalty for task failure were considered together in the offloading model designation. An online algorithm based on Lyapunov optimization is proposed to jointly determine edge server site selection and energy harvesting. Work [16] investigated computation offloading in a dynamic MEC system with multiple edge servers, where computational tasks with various requirements were dynamically generated by IoT devices and then offloaded to MEC servers in a time-varying operating environment. The objective of this work is to maximize the task completion time and minimize the energy consumption of IoT devices. In [17], the authors used an improved glowworm swarm optimization algorithm to solve the task offloading problem for a multiuser-multi-MEC environment. Also, the authors in work [18] presented a reinforcement learning framework based on the theory of stochastic learning automata towards enabling the end-users to select an MEC server to offload their data. To realize the proposed framework, an iterative and low-complexity algorithm is introduced and designed. Literature [19] proposed a cooperative offloading technique based on the Lagrangian suboptimal convergent computation offloading algorithm (LSCCOA) for multiaccess MEC in a distributed Internet of Things (IoT) network. However, none of the abovementioned methods considered the weight of the offloaded tasks. In fact, different tasks are of different importance to users.

To indicate the importance of different tasks, the authors in [20] proposed a multiobjective task scheduling algorithm, which aimed to optimize the allocation of the weight of the offloaded tasks. However, this work has the following limitations. First, tasks in this work can be offloaded to an edge server only. Second, the energy consumption of the mobile terminal was ignored. Finally, a bat algorithm was

used in this work to get the optimization result. Since the bat algorithm has no mutation operation, sometimes, the solutions are lack of diversity. Specifically, Table 1 shows the differences between some related studies and our work proposed in this paper.

In this paper, the proposed model takes many aspects of task offloading into account. Moreover, the bat algorithm is combined with an immune algorithm to improve the performance of the bat algorithm and get better optimization results. Meanwhile, the scenario that mobile devices can generate multiple tasks simultaneously is considered. To the best of our knowledge, each device can only generate only one task in the related studies. Hence, our work is more realistic compared with relevant studies.

3. System Model and Problem Formulation

3.1. System Model. Suppose the proposed system consists of n IMDs and m MEC servers. Let $D = \{D_1, D_2, \ldots, D_n\}$ denote the set of IMDs and $\mathrm{CS} = \{\mathrm{CS}_1, \mathrm{CS}_2, \ldots, \mathrm{CS}_m\}$ denote the set of MEC servers. We also discretize time into multiple time slots, and all time slots have equal length as σ.

Among set CS, one edge server in the central location is selected as the controller. The proposed HIBSA algorithm, which is detailed in Section 4, is executed on this controller. In each time slot σ, the IMDs generate computation task requests. Those requests along with the basic information of the IMDs (e.g., app type, local CPU-cycle frequency, and battery energy level) are then sent to the controller. By executing the HIBSA algorithm, the controller chooses the edge server for each IMD for task offloading. The architecture of this system model is shown in Figure 1.

For any IMD $D_i \in D$, there exists a task queue $T^i = (T^i_1, T^i_2, \ldots, T^i_k, \ldots)$, where T^i_k denotes the k-th task generated by the i-th IMD at a certain time slot. For task T^i_k, it can be denoted by four tuples $(\mathrm{dnum}_{ik}, \mathrm{cnum}_{ik}, w_{ik}, \varphi_{ik})$, where dnum_{ik} is the size of the input data for computation, cnum_{ik} is the CPU cycles to be processed for offloading, w_{ik} is the weight of the task, and φ_{ik} is the remaining battery energy value of this IMD when generating this task. All generated tasks can be divided into two types. One is the real-time task, and another is the delay-tolerant task. The real-time task owns a maximum latency and must be finished before the delay threshold whereas the delay-tolerant task can tolerate a much longer delay.

Furthermore, we use a binary matrix $s = \{s_{ij} | s_{ij} \in (0,1)\}_{n \times m}$ to represent one scheduling solution, where $s_{ij} = 1$ denotes that the latest task generated by the i-th IMD is allocated to the j-th server in this scheduling solution, while $s_{ij} = 0$, otherwise.

3.2. Performance Evaluation. For any scheduling solution, its performance is described by a vector (time cost and weight), where time cost is the sum of the time consumption for executing all tasks. Moreover, time cost consists of two parts: one is the time delay for successfully completed tasks, and the other is the punishment time for failed tasks. The time t_{ik} for successfully finishing task T^i_k is as follows:

$$t_{ik} = t_{comm} + t_{comp} + t_{coor} + t_{local}, \tag{1}$$

where t_{comm} is communication cost and is denoted as

$$t_{comm} = \max_{j \in CS, s_{ij}=1} \frac{\mathrm{dnum}_{ik}}{C_{ij} \cdot \sum_{j \in CS} s_{ij}}, \tag{2}$$

where C_{ij} is the approximate data rate between the i-th IMD and the j-th edge server, based on the 3GPS TS 38.306; the transmission rate is as follows:

$$C_{ij} = 10^{-6} \cdot \sum_{k=1}^{K} \left\{ v^{(k)}_{Layers} \cdot Q^{(k)}_m \cdot f^{(k)} \cdot R_{\max} \cdot \frac{N^{BW(k),\mu}_{PRB} \cdot 12}{T^{\mu}_S} \cdot \left(1 - \mathrm{OH}^{(k)}\right) \right\}, \tag{3}$$

where K is the number of aggregated component carriers (CC) in a band or band combination between the i-th IMD and the j-th edge server. $R_{\max} = 948/1024$. For the k-th CC, $v^{(k)}_{Layers}$ is the maximum number of layers; $Q^{(k)}_m$ is the maximum modulation order; $f^{(k)}$ is the scaling factor; μ is the numerology; T^{μ}_S is the average OFDM symbol duration in a subframe for numerology μ; $N^{BW(k),\mu}_{PRB}$ is the maximum RB allocation in bandwidth $BW^{(k)}$ with numerology μ, where $BW^{(k)}$ is the supported maximum bandwidth in the given band or band combination between the i-th IMD and the j-th edge server; and $\mathrm{OH}^{(k)}$ is the overhead. t_{comp}, which is the time for computing this offloaded task, is given as

$$t_{comp} = \max_{j \in CS, s_{ij}=1} \frac{\mathrm{cnum}_{ik}}{f_j \cdot \sum_{j \in CS} s_{ij}}, \tag{4}$$

where f_j is the CPU cycle frequency of the j-th edge server and t_{coor} is the coordination cost between multiple servers and is calculated as follows:

$$t_{coor} = u_{lc} \cdot \sum_{j \in CS} s_{ij}, \tag{5}$$

where u_{lc} is the unit latency cost and t_{local} is local execution time that includes data preprocessing time and data packing time. t_{local} is given as

$$t_{local} = \frac{c_{ik}}{f_i}, \tag{6}$$

where c_{ik} is the amount of CPU cycles to process the local execution and f_i is the CPU cycle frequency of the i-th IMD. Besides, t_{ik} should satisfy

Table 1: The differences between several references and our work.

Related works	Problem formulation	Optimization objectives	Algorithm proposed
[15]	Markov decision process (MDP)	Minimize the overall delay cost of all mobile devices subject to some constraints	The sampling and classification (SAC) based edge site selection (SES) algorithm
[18]	A two-layer optimization framework	Maximize its profit by processing the end-users' data for each MEC server while maximizing its perceived satisfaction for each end-user	Data offloading and MEC server selection (DO-MECS) algorithm
[19]	Single-objective optimization problem with multiple constraints	Lessen the weighted amount of power consumed by communicating devices subject to some constraints	The Lagrangian suboptimal convergent computation offloading algorithm (LSCCOA)
[20]	Multiobjective optimization problem with multiple constraints based on Pareto	Minimize the total execution time and maximize the total weight under the constraints of communication and computing resources	Bat algorithm
Our method	Multiobjective optimization problem with multiple constraints based on Pareto	Minimize the total execution time and maximize the total weight under the constraints of communication, computing and energy resources	Hybrid immune and bat scheduling algorithm (HIBSA)

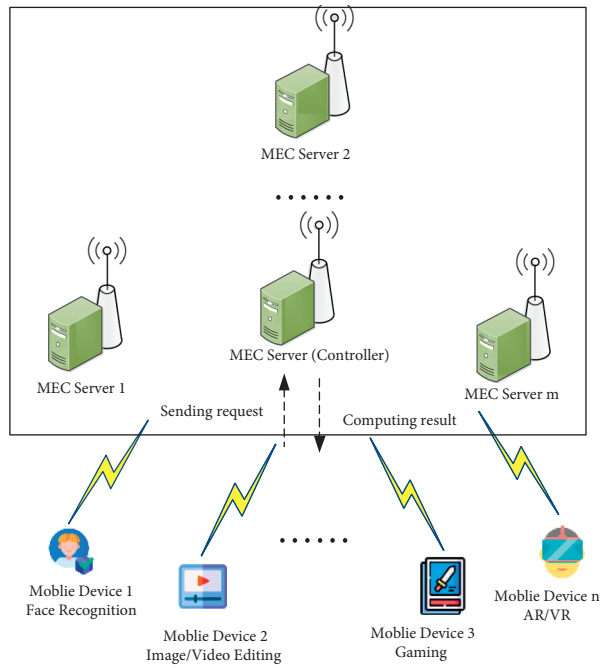

Figure 1: The architecture of system model.

$$t_{ik} \leq \mathrm{TC}_{ik}, \tag{7}$$

where TC_{ik} is the execution deadline of this task. Successfully completed tasks are put into the successful set G_{suc}. Accordingly, the whole time consumption for successfully completed tasks is $\sum_{i \in G_{suc}} t_{ik}$.

There are two possibilities for the failed task. One is the task is overtime, namely, $t_{ik} > \mathrm{TC}_{ik}$. These tasks must be omitted or wait for the next time to be scheduled again, which depends on the type of the task. The other is that the task is not assigned to any server in this schedule at all, namely, $\sum_{j \in CS} s_{ij} = 0$. These tasks also need to wait for the next schedule or to be omitted. In these conditions, a time punishment F was given ($\mathrm{F} > \mathrm{TC}_{ik}$), and the failed tasks are put into unsuccessful set G_{fail}. Thus, at a certain time slot σ, the total time cost of all the scheduling is defined as follows:

$$t_{all} = \Sigma_{i \in G_{suc}} t_{ik} + \left| G_{fail} \right| \cdot F. \tag{8}$$

Another evaluation metric is weight. The sum of the weights of all successfully offloaded tasks is

$$w = \sum_{i \in S_{suc}} w_i. \tag{9}$$

3.3. Problem Formulation. For the task scheduling problem involved in this paper, there are $2^{n \times m}$ possible scheduling solutions. The set of scheduling solutions is denoted as S. The

optimization goal of this model is to find a scheduling $s(s \in S)$ under the constraints of communication, computing, and energy resources, which can minimize the total execution time and maximize the total weight. Here, any scheduling solution should satisfy two constraints: one is the computing resources constraint, which is shown as

$$\forall_{j \in CS} \sum_{i \in D} s_{ij} \leq M_j, \tag{10}$$

which means that the j-th server can be assigned up to at most M_j tasks due to its limited computational capability. The other one is the energy consumption constraint, which is shown as

$$\varepsilon_l + \sum_{j \in CS} \varepsilon_{i,j}^{tx} \cdot s_{ij} \leq \varphi_{ik}, \tag{11}$$

where ε_l is the energy consumption of local execution and ε_{ij}^{tx} is the energy consumption for transmitting between the i-th IMD and the j-th edge server and is given by

$$\varepsilon_{i,j}^{tx} = p_i^{tx} \cdot t_{comm}, \tag{12}$$

where p_i^{tx} represents the fixed transmit power of the IMD$_i$. Formula (11) means the total energy consumption of the i-th IMD must be less than the current battery energy value of this device.

Therefore, the proposed task scheduling problem can be formulated as the following combinatorial optimization problem P:

$$\begin{aligned} \mathrm{P} \begin{cases} \min f_1(s) = t_{all} = \Sigma_{i \in G_{suc}} t_{ik} + \left| G_{fail} \right| \cdot F, \\ \min f_2(s) = w = -\sum_{i \in S_{suc}} w_i, \end{cases} \\ s.t. \quad C1: \ \forall_{j \in CS} \sum_{i \in D} s_{ij} \leq M_j, \\ C2: \ \varepsilon_l + \sum_{j \in CS} \varepsilon_{i,j}^{tx} \cdot s_{ij} \leq \varphi_{ik}. \end{aligned} \tag{13}$$

3.4. Demo. In this section, a simple demo was given to illustrate the task scheduling problem in multiple server environments. As shown in Figure 2, suppose there are three devices (D_1, D_2, and D_3) and two MEC servers (CS_1 and CS_2) in the system, and there are three queues T^1, T^2, T^3, respectively. At the first time slot, tasks in each queue are denoted as $T_1^1(2, 2, 1, 1), T_1^2(5, 5, 3, 2), T_1^3(3, 3, 1, 1)$, respectively.

For simplify, we make the following assumptions: (1) each MEC server can run only one task at one time; (2) the delay constraint of all these three tasks is 7, namely $Tc = 7$; (3) the data transmission rate C_{ij}, the computation rate η_j, and the unit data energy consumption of transmission between i-th IMD and j-th server ε_{ij}^{tx} are all assumed to be 1; (4) the local execution time, energy consumption, and the coordination cost are ignored, namely $\varepsilon_l = 0$ and $t_{coor} = t_{local} = 0$. As shown in Table 2, three task scheduling solutions are given.

Since $s1$ cannot meet constraints (10) and (11), it is invalid scheduling. $s2$ satisfies constraints (10) and (11).

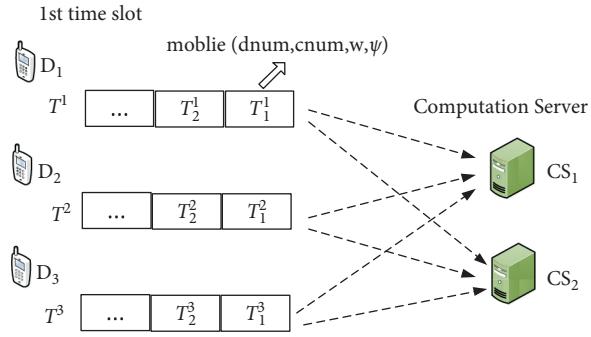

Figure 2: Initial condition of DEMO.

Table 2: Solutions.

Solution s	CS\D	D_1	D_2	D_3
$s1$	CS_1	1	1	1
	CS_2	1	1	1
$s2$	CS_1	1	0	0
	CS_2	0	0	1
$s3$	CS_1	0	1	0
	CS_2	0	1	0

According to formula (1), the task completion time of T_1^1 is 4, which is less than the delay constraint. Therefore, this is a successful offloading, and sequence number 1 is put into set G_{suc}. As a result, $G_{suc} = \{1\}$. T_1^2 is not assigned any computing server in this scheduling, so sequence number 2 is put into the failure set G_{fail}. According to formula (1), the task completion time of T_1^3 is 6, which is less than the delay constraint value. Since it is a successful offloading, sequence number 3 is put into the success set G_{suc}, and G_{suc} is updates to $\{1, 3\}$. According to formulas (8) and (9), $t_{all} = 4 + 6 + F = 10 + F$ and $w = 2$. Also, $s3$ satisfies the constraints (10) and (11). T_1^1 is not assigned any computing server in this scheduling. Thus, $s3$ is a failed offloading. According to formula (1), the completion time of T_1^2 is 5. Therefore, this is a successful offloading, and sequence number 2 is put into the success set G_{suc} and $G_{suc} = \{2\}$. T_1^3 is not assigned any computing server in this scheduling, so it is a failed offloading. Thus, we have $t_{all} = 5 + 2F$ and $w = 3$.

In all, none of these scheduling schemes has both the least time consumption time and the largest task completion weight. Generally, the best solution that meets all the objectives cannot be found. However, the noninferior solution can be found.

4. Proposed Algorithm

4.1. Multiobjective Optimization Problem

4.1.1. Problem Statement. The general description of the multiobjective optimization problem is as follows:

Given the vector $X = (x_1, x_2, \ldots, x_n) \in R^n$, and it satisfies the following constraints:

$$g_i(X) \le 0 \, (i = 1, 2, \ldots, k), \tag{14}$$

$$h_i(X) = 0 \, (i = 1, 2, \ldots, l). \tag{15}$$

Suppose that there are r optimization objectives, which are in conflict with each other. The optimization objective can be expressed as follows:

$$\min f(X) = \min\left(f_1(X), f_2(X), \ldots, f_r(X)\right). \tag{16}$$

We want to find $X^* = (x_1^*, x_2^*, \ldots, x_n^*)$ in order that $f(X^*)$ can be optimized while satisfying constraints (14) and (15). Obviously, the scheduling problem mentioned in this paper is a multiobjective optimization problem. Generally, it is necessary to consider the conflicting subobjectives comprehensively and make the trade-off among the subobjectives.

4.1.2. Pareto-Optimal Set. Multiobjective optimization is to simultaneously optimize multiple subobjectives, and these subobjectives often conflict with each other. The optimization of one objective may result in the deterioration of another objective. Normally, no single solution can optimize all the objectives simultaneously. The trade-off among multiobjectives can be properly attained by using Pareto optimality [21].

Definition 1 (Pareto dominance). A decision vector X_A is said to dominate another decision vector X_B (noted as $X_A \succ X_B$) if and only if

$$\forall_{i=1,2,\ldots,r,} \, f_i(X_A) \le f_i(X_B) \wedge \exists_{j=1,2,\ldots,r,} \, f_j(X_A) < f_j(X_B). \tag{17}$$

Definition 2 (Pareto optimal). A solution $X^* \in X_f$ is said to be Pareto optimal if and only if

$$\neg \exists X' \in X_f : \; f_j(X^*) \ge f_j(X'), \quad \forall j = 1, 2, \ldots, r, \tag{18}$$

where X_f represents the set of solutions.

Definition 3 (Pareto-optimal set). Set P^* includes all Pareto-optimal solutions, which can be defined as follows:

$$P^* = \{X^*\} = \left\{X \in X_f \mid \neg \exists X' \in X_f : \; f_j(X) \ge f_j(X'), \quad \forall j = 1, 2, \ldots, r\right\}. \tag{19}$$

4.1.3. General Framework of MOEA Based on Pareto. An evolutionary algorithm (EA) is a kind of random search algorithm that simulates the natural selection and evolution of organisms. It is widely used because it is suitable for solving highly complex nonlinear problems. At the same time, it has good versatility. The advantages of EA have been fully demonstrated in solving single objective complex system optimization problems. However, EA cannot resolve multiobjective optimization problems effectively. For the multiobjective optimization problem, it can be resolved by the multiobjective evolutionary algorithm (MOEA). Over the last decades, the design method of MOEA has attracted great interest of researchers [22–24].

Most MOEAs adopted the general process, which is shown in Figure 3. The whole process of MOEA is described as follows. Firstly, an initial population P is generated, and an algorithm is selected to operate on P to obtain a new evolutionary population R. Next, a strategy is adopted to construct the nondominated set (NDSet) of P∪R. Generally, the set size is set when designing the algorithm (such as N). If the size of the current set is greater than or less than N, the size of the NDSet needs to be adjusted according to a certain strategy. In the adjusting process, the NDSet must meet both the size requirements and the individual diversity. Then whether the termination condition is satisfied is judged. The process ends if and only if the termination condition is satisfied. Otherwise, we need to copy the individuals in NDSet to P and continue to the next round of evolution.

4.2. Individual Evaluation Method. Different from the single-objective optimization problem, the multiobjective optimization problem needs vector comparison. The multiobjective optimization strategy adopted in this paper is similar to the method of NGSA-II [25–27], but some changes have been made. All scheduling schemes are divided into three types. For any scheduling s of the first type, it can complete all tasks on the premise of satisfying constraints (10) and (11). Obviously, this type of scheduling is ideal, so it is set to the highest rank 0, namely $rank_s = 0$. The scheduling of the same level is ranked according to the task completion time, and the higher priority value has little task completion time. The second type is also to satisfy constraints (10) and (11), but it can only complete a part of offloaded tasks. We regard each scheduling s of this type as an individual in the evolutionary algorithm. According to the NSGA-II method [28], all individuals in the first nondominated front are found firstly. In order to find the individuals in the next nondominated front, the solutions of the first front are discounted temporarily, and the above procedure is repeated. The rank of the scheduling s in the first front is 1, namely $rank_s = 1$. Similarly, the rank of the scheduling in the second front is 2, so back and forth. Compared with the crowding distance of individuals in the same rank, individuals with higher aggregation density have a higher priority value. The third type is the scheduling that violates constraints (10) and (11). Assuming that the second type is divided into n ranks, for the scheduling s that belongs to the third type, its rank is $n+1$, namely $rank_s = n + 1$. The scheduling that violates constraint (10) to a lower degree has a higher priority. According to the abovementioned method, suppose there are scheduling p and scheduling q, the comparison strategy between them is described in Algorithm 1.

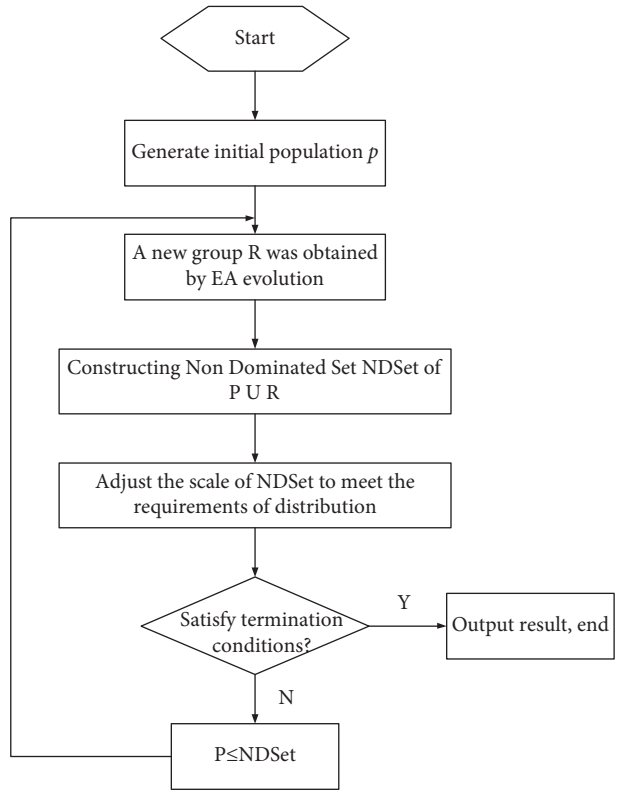

Figure 3: General flow of multiobjective evolutionary algorithm based on Pareto.

4.3. Our Algorithm

4.3.1. Bat Algorithm. As mentioned above, the basis of multiobjective evolutionary algorithm is an evolutionary algorithm. At present, the most commonly used evolutionary algorithms include simulated annealing algorithm, genetic algorithm, distribution estimation algorithm, and particle swarm optimization algorithm. However, in these algorithms, the individual's movement mode does not adopt the position update mode of the deterministic algorithm. That is, "only move to the solution that is better than the current position" method is used. Yang [29] proposed a bat algorithm (BA) that adopts the method of "only move to the solution which is better than the current position." BA simulates the behavior of microbats in nature, which uses echolocation to hunt prey and avoid obstacles. Compared with other evolutionary algorithms, BA has the characteristics of higher computational efficiency, stronger optimization ability, and robustness.

According to the bat's echolocation behavior and its correlation with objective optimization, the parameters and updating equations of n bats during flight are given below: Suppose that there are n virtual bats living in the domain. In the t-th generation, the information containing the i-th ($i = 1, 2, \ldots, n$) bat can be expressed as five tuples: $\langle \overrightarrow{x_i}(t)t, n\overrightarrow{v_i}q(t)h, {}_f xr_i 7(t)C, ; A_i(t), r_i(t)\rangle$, where $\overrightarrow{x_i}(t) = (x_{i1}(t), x_{i2}(t), \ldots, x_{ik}(t), \ldots, x_{iN}(t))$ denotes the position information of the t-th generation of the i-th bat and a solution of the search space, the speed $\overrightarrow{v_i}(t) = (v_{i1}(t), v_{i2}(t), \ldots, v_{ik}(t), \ldots, v_{iN}(t))$ represents the velocity direction of the i-th bat in the t-th generation, while frequency $fr_i(t)$, loudness $A_i(t)$, and pulse emission frequency $r_i(t)$ are three parameters needed by i-th bat in the algorithm. In the $(t+1)$-th generation, each bat firstly updates its speed according to the formula, which is described as follows:

$$v_i(t+1) = v_i(t) + \left(x_i(t) - \mathrm{p}(t) \cdot fr_i(t)m, \right. \tag{20}$$

where $\overrightarrow{p}(t) = (p_1(t), p_2(t), \ldots, p_k(t), \ldots, p_N(t))$ indicates the historical optimal position of the previous t generations, while $(x_i(t) - \mathrm{p}(t))\mathrm{fr}_i(t)$ represents the effect of the deviation between $\overrightarrow{x_i}(t)$ and $\overrightarrow{p}(t)$ on the speed of the next generation, and the frequency $fr_i(t)$ is randomly generated according to the following formula:

$$\mathrm{fr}_i(t) = fr_{\min} + \left(fr_{\max} - fr_{\min}\right) \cdot \mathrm{rand}_1, \tag{21}$$

where rand_1 is a uniformly distributed random number in (0, 1) and the two parameters fr_{max} and fr_{min} are the preset as the upper and lower frequency limits, respectively.

On this basis, when each bat performs a global or local search, the selection of its search mode is determined in a random way. It means random number $rand_2$, which is uniformly distributed between 0 and 1 needs to be determined. If $\mathrm{rank}_2 < r_1(t)$, the i-th bat will search for food in the following global search mode:

$$x_i'(t+1) = x_i(t) + v_i(t+1). \tag{22}$$

(1) If $(\text{rank}_p < \text{rank}_q)$
(2) $\quad p \succ q$
(3) If $(\text{rank}_p = \text{rank}_q = 0$ and $t_p < t_q)$
(4) $\quad p \succ q$
(5) **If** $(\mathbf{rank_p = rank_q = n+1}$ **and** $\sum_{\mathbf{j}\in\mathbf{cs}} \mathbf{max}(\sum_{\mathbf{i}\in\mathbf{D}} \mathbf{p_{ij}} - \mathbf{M_j}, \mathbf{0}) < \sum_{\mathbf{j}\in\mathbf{cs}} \mathbf{max}(\sum_{\mathbf{i}\in\mathbf{D}} \mathbf{q_{ij}} - \mathbf{M_j}, \mathbf{0}))$
(6) $\quad p \succ q$
(7) If $(1 \le \text{rank}_p \le n$ and $1 \le \text{rank}_q \le n$ and $d_p > d_q)$
(8) $\quad p \succ q$
(d_p and d_q represent the aggregation density of p and q, respectively)

Algorithm 1: Individual evaluation algorithm (IEA).

Otherwise, the i-th bat will perform a local search according to the following formula:

$$x_i'(t+1) = p(t) + \varepsilon_i \cdot \overline{A(t)}, \tag{23}$$

where ε_i is a uniformly distributed random number belongs to (−1, 1) and $\overline{A(t)} = \sum_{j=1}^{n} A_j(t)/n$ is the average loudness of the bat at the t-th time.

After the new location $\overrightarrow{x_i'}(t+1) = (x_{i1}'(t), x_{i2}'(t), \ldots, x_{ik}'(t), \ldots, x_{iN}'(t))$ is calculated, the bat will be judged whether to move instead of moving to the new location immediately according to the following update rules:

$$\overrightarrow{x_i}(t+1) = \begin{cases} \overrightarrow{x_i'}(t+1), & \text{rand}_3 < A_i(t) \text{and} f\left(\overrightarrow{x_i'}(t+1)\right) < f\left(\overrightarrow{x_i}(t)\right), \\ \overrightarrow{x_i}(t), & \text{else.} \end{cases} \tag{24}$$

When updating the position, a uniformly distributed random number $rand_3$ that belongs to (0, 1) was selected. When $\text{rand}_3 < A_i(t)$ and $f(\overrightarrow{x_i'}(t+1)) < f(\overrightarrow{x_i}(t))$ are satisfied simultaneously, the i-th bat updates the location to $\overrightarrow{x_i}(t+1)$. Otherwise, the location of i-th bat is still $\overrightarrow{x_i}(t)$ without updating the location to $\overrightarrow{x_i}(t+1)$.

The update formula of the pulse emission rate $r_i(t+1)$ is as follows:

$$r_i(t+1) = r_i(0) \cdot \left(1 - e^{-\gamma t}\right). \tag{25}$$

Loudness $A_i(t+1)$ is updated as follows:

$$A_i(t+1) = \alpha A_i(t), \tag{26}$$

where $\alpha > 0$ and $\gamma > 0$ are both preset parameters, $A_i(0)$ is the initial value of loudness, and $r_i(0)$ is the initial value of pulse emission rate. In the paper, $A_i(0)$ is random selected from [0, 1] and $r_i(0) = 0.1$.

In the basic bat algorithm, equations (20) and (22) represent the global search mechanism of the algorithm, while equation (23) represents the local search mechanism of the bat algorithm.

4.3.2. Hybrid Immune Bat Algorithm. It was shown that the optimization ability of BA mainly depends on the interaction and influence between bat individuals. Due to the lack of a mutation mechanism, it is difficult for individuals to get rid of the constraint of a local extreme value. Moreover, in the evolution process, the super bats in the population may attract other individuals to gather around them quickly, which results in a significant decline in population diversity. Meanwhile, the bat individuals are getting closer to the optimal individuals of the population in order that the population has lost the ability of further evolution [30]. In this paper, the clonal selection mechanism in the artificial immune system is introduced, which can enhance the diversity of bat population, enhance the ability of wide range variation, and increase the convergence rate.

Suppose that an individual population $B = \{b_1, b_2, \ldots, b_n\}$ is obtained through the process of the bat algorithm, which is a temporary clonal population. Each bat i ($i = 1, 2, \ldots, n$) in the temporary clonal population is regarded as an antibody. The specific methods are as follows:

Step 1: the k ($k < n$) antibody individuals selected in a random way were grouped into subpopulation $\text{Sub}_1 = \{b_1', b_2', \ldots, b_k'\}$. And clone and copy subpopulation Sub_1. The cloning operator is described as follows:

$$\text{Sub}_2 = T_c(\text{Sub}_1) = [T_C(b_1'), T_C(b_2'), \ldots, T_C(b_k')], \tag{27}$$

where $T_C(b_i') = q_i \times b_i'$, $(i = 1, 2, \ldots, k)$, where q_i is the number of clones of b_i', which is proportional to the fitness of b_i'. A new population Sub_2 was generated by cloning.

Step 2: implement high-frequency mutation for each individual in group Sub_2, and the mutation operator is adaptive, which is related to both evolution generations and individual fitness. For any $b_i' = (b_{i1}', b_{i2}', \ldots, b_{ij}', \ldots, b_{in}')$, the mutation formula is given as follows:

$$b_{ij}^{'new} = \begin{cases} \sim b_{ij}^{'old}, & \text{rand}_4 < \eta(t) \text{ and } \text{rand}_5 < \Delta, \\ b_{ij}^{'old}, & \text{else.} \end{cases} \quad (28)$$

$\eta(t)$ in formula (28) is given as follows:

$$\eta(t) = 1 - r_1^{[1-(t/T)]^b}, \quad (29)$$

where b is a positive constant, $r_1 \in (0, 1)$. In the early stages of evolution, $r_1^{[1-(t/T)]^b}$ was smaller, $\eta(t) \approx 1$, but in the later stage of evolution, when t approaches T, $\eta(t) \approx 0$, local search is carried out in a small space. Furthermore, Δ in formula (28) is formulated as follows:

$$\Delta = 1 - r_2^{R^\lambda}, \quad (30)$$

where $r_2 \in (0, 1)$, the parameter λ plays the role of adjusting the search area, and the value is generally 2–5 [31]. R in the above formula is formulated as follows:

$$R = 1 - \frac{\text{fit}(b_i')}{\text{fit}_{\max}}, \quad (31)$$

where $\text{fit}(b_i')$ represents the fitness of antibody b_i' and fit_{max} is the maximum fitness value, which is the aggregation density of the individual. Obviously, for those with higher fitness, the Δ value is smaller, and the mutation possibility is small, while for those with lower fitness, the mutation possibility is relatively large.

Step 3: immune clonal selection: the best individual from the clonal mutation individuals is selected for the next generation. The full algorithm of HIBSA is given in Algorithm 2.

4.3.3. The Full Algorithm of HIBSA. 4.4. Time Complexity Analysis. In this section, the time complexity of HIBSA is analyzed. Based on the flowchart in Figure 3, assuming that the population P size, the new group R size are both N, the number of objectives is M (in fact, M is 2 in this paper). The number of decision valuables is $m \times n$ (n is the number of IMDs and m is the number of MEC servers). The basic operators and their time complexity analysis are given as follows:

(1) Generate initial population P. Population initialization is to generate individuals randomly and calculate the values of objectives, so the time complexity is $O(m \times n \times N) + O(M \times N)$.

(2) A new group R was obtained by EA evolution. In this paper, the evolutionary algorithm combines the bat algorithm and the immune algorithm together. In both these two algorithms, identifying nondominated individuals was needed. When identifying nondominated individuals, individuals are compared with each other based on the objectives. Hence, the time complexity is $O(M \times N^2)$.

(3) Construct nondominated set (NDSet) of P∪R. As these operators are performed in the P∪R, so the time complexity of nondominated individuals identification is $O(M \times (2N)^2)$

(4) Adjust the scale of NDSet to meet the requirements of distribution. In this stage, adjust operator selects nondominated individuals with greater fitness values to preserve. Therefore, in the assignment of fitness values, the time complexity of the crowding-distance assignment is $O(M \times N \times \log(N))$.

Based on the above analysis, in a single generation, the worst time complexity can be written as follows:

$$O\left(M \times N^2\right). \quad (32)$$

5. Experimental Evaluation

In this section, we evaluate the performance of HIBSA through simulations and compare its performance against several algorithms.

5.1. Verification Policies. Suppose that at one time, there are n mobile devices and m computing servers, and each device currently has a task queue to be offloaded. Assuming that on the t-th slot, the k-th task T_i^k in the current queue on the i-th device is ready to be offloaded. If the offloading is successful, the device intends to offload the next scheduling task in the queue at the $(t+1)$-th slot, which means the $(k+1)$-th task T_i^{k+1} prepares to be offloaded. However, if task T_i^k fails to be offloaded at the t-th slot, the current task T_i^k can be omitted or wait to be scheduled at the $(t+1)$-th slot, which is decided by whether the task is a real-time task or not. In order to verify the performance of the proposed scheduling algorithm, it is compared with sequential scheduling algorithm (SSA), random scheduling algorithm (RSA), time priority greedy scheduling algorithm (TPGSA), and weight priority greedy scheduling algorithm (WPGSA). The comparison algorithms are described as follows:

(1) SSA: the scheduling is carried out according to the equipment number, and the one with a small equipment number is scheduled first.

(2) RSA: in this method, each task is scheduled randomly.

(3) TPGSA: at one time, all tasks to be scheduled are sorted by the expected completion time. The shorter the task completion time, the earlier the task is scheduled.

(4) WPGSA: at one time, all the tasks to be scheduled are sorted by the task weight.

The experimental platform used in this paper is MATLAB 2016a [32], and the main simulation parameters are presented in Table 3.

(1) The scheduling population P^0 is randomly generated, the population size is n, and the initialization generation $t = 0$
(2) According to the individual evaluation algorithm, all the individuals of rank 0 and rank 1 in P are put into the set P_0^t and P_1^t, respectively
(3) If $(P_0^t \neq \Phi)$
select the optimal solution in P_0^t as the result and the algorithm ends
(4) else
(5) while $(t < T)$
(6) A solution is randomly selected from P_1^t as the historical optimal position of the current population, and BA is implemented for P^t to get P_B^t
(7) Clear set P_0^t, P_1^t. According to the individual evaluation algorithm, all the individuals of rank 0 and rank 1 in the set P_B^t are put into the set P_0^t and P_1^t, respectively
(8) If $(P_0^t \neq \Phi)$
(9) select the optimal solution in P_0^t as the result and the algorithm ends
(10) else
(11) For P_B^t, the immune clonal selection algorithm is implemented to get P_I^t
(12) Clear set P_0^t and P_1^t. According to the individual evaluation algorithm, all the individuals of rank 0 and rank 1 in the set P_B^t are put into the set P_0^t and P_1^t, respectively
(13) If $(P_0^t \neq \Phi)$
(14) select the optimal solution in P_0^t as the result and the algorithm ends
(15) else
(16) According to the individual evaluation algorithm, put the first n individuals in the set $P_B^t \cup P_I^t$ into P^{t+1}
(17) $t = t + 1$
(18) end if
(19) end if
(20) end while
(21) end if
(22) select a solution randomly from P_1^t as the result and the algorithm ends

Algorithm 2: Hybrid immune and bat scheduling algorithm (HIBSA).

Table 3: Simulation parameters for task offloading.

Parameter	Value	Note
m	3–5	Number of MEC servers
dnum	[1–7] Mb	The size of the input data
u_{cc} [20]	1,000 cycles/bit	Unit CPU cycles (per bit)
F	8 GHz	The CPU cycle frequency of CS
u_{lc}	0.05 ms	Unit latency cost
TC	5 ms	Maximum latency
M_j	5 tasks	MEC server computing capacity
p_i^{tx}	0.1 W	Fixed transmit power of IMD
φ	40 mJ	Safe discharge threshold
N	10	Number of IMDs
w_i	[1–100]	Task weight
fr_{max} [33–36]	2	The upper frequency of bat
fr_{min} [33–36]	0	The lower frequency of bat
α [37–39]	0.9	The update parameter of the loudness of bat
γ [37–39]	0.1	The update parameter of the pulse emission rate of bat
N	30	Number of initialization populations
Gen	30	Number of generations

5.2. Experimental Result. In this section, experimental results are given. Due to the limitation of space, we only show the experimental data of the first 20 time slots.

5.2.1. Execution Time Analysis. The results about total task execution time in the first 20 time slots obtained by the five algorithms are shown in Table 4.

We take the task completion time of TPGSA as the benchmark and normalize its value to 1. Thus, the comparison of the results about the task completion time of these five algorithms at 20 time slots is shown in Figure 4:

We can see from Figure 4 that SSA, RSA, and WPGSA are all not as good as TPGSA in task execution time. However, the performance of HIBSA is better than TPGSA. As shown in Figure 5, if the average execution time of the TPGSA algorithm is 1, the average task execution time of the SSA algorithm is 1.04; the average scheduling time of the RSA algorithm is 1.13; and the average scheduling time of the WPGSA algorithm is 1.05. However, the task execution

Table 4: The total task execution time in the first 20 time slots.

T	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SSA	66	120	167.33	228	293.33	346.67	419.33	485.33	558	618	690	749.33	815.33	880.67	940	994	1,059.33	1,112.67	1,178.67	1,244
RSA	66.67	130	196.67	262	324.67	380	454.67	535.33	604	668.67	738	810.67	878.67	949.33	1,015.33	1,088.67	1,167.33	1,234	1,316	1,396
TPGSA	54.00	107.33	160.67	220.67	280.67	340.00	406.00	466.00	539.33	605.33	670.67	736.00	796.00	862.00	926.67	992.67	1,058.67	1,118.00	1,171.33	1,236.67
WPGSA	73.33	120.67	167.33	240.67	313.33	360.00	407.33	480.00	534.00	607.33	680.00	732.67	804.00	876.00	949.33	1,020.67	1,073.33	1,146.00	1,186.67	1,258.67
HIBSA	54	95.33	134.67	188	261.33	334	370.67	428	501.33	552.67	622.67	689.33	762.67	835.33	887.33	940	999.33	1,072.67	1,108.67	1,174

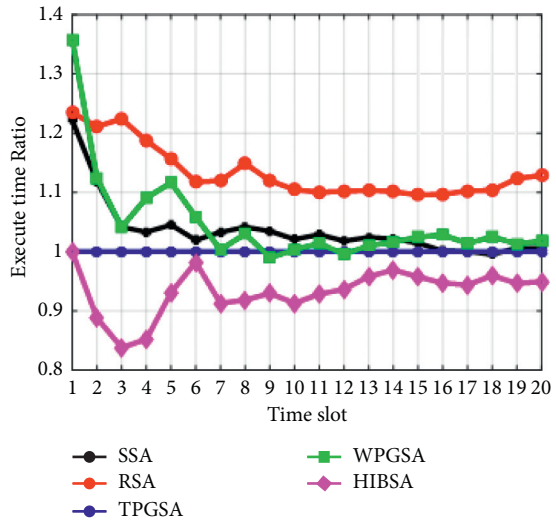

Figure 4: Comparison of task execution time ratio of various algorithms of 20 time slots.

time of HIBSA is only 0.93. That is, the scheduling time of the algorithm proposed in this paper is only 93% of the TPGSA algorithm.

5.2.2. Weight Analysis. The results about the sum of task weight in the first 20 time slots of the five algorithms are shown in Table 5.

We take the weight of WPGSA as the benchmark and normalize its value to 1. Thus, the comparison of the results about the weight of each algorithm at 20 time slots is shown in Figure 6:

Taking WPGSA as the benchmark, SSA, RSA, and TPGSA are not as good as WPGSA in weight, while HIBSA proposed in this paper is better than WPGSA sometimes and slightly worse than WPGSA. As shown in Figure 7, if the average scheduling weight of WPGSA is 1, the average scheduling weight of SSA is 0.92; the average scheduling weight of RSA is only 0.59; and the average scheduling weight of TPGSA is 0.87, while the scheduling weight of HIBSA is slightly worse than WPGSA. According to the scheduling strategy proposed in the paper, the scheduling weight of the proposed algorithm is 98% of WPGSA.

5.2.3. Analysis of the Total Number of Offloaded Tasks. The total number of tasks offloaded by each device in the first 20 time slots by using different algorithms is shown in Table 6

As shown in Table 6, 10 devices offload 132 tasks in 20 time slots by using SSA. RSA algorithm offloads 93 tasks only. TPGSA offloads 133 tasks. WPGSA offloads 130 tasks, while HIBSA has the largest number of offloaded tasks. This is because the algorithm proposed in this paper is a multiobjective optimization algorithm, and it also takes fairness into consideration in task scheduling. Figure 8 is a comparison box plot of the number of scheduling devices using these five algorithms. As shown in Figure 8, the quartile deviation between the SSA algorithm and the TPGSA algorithm is large, which results in the unfairness of the

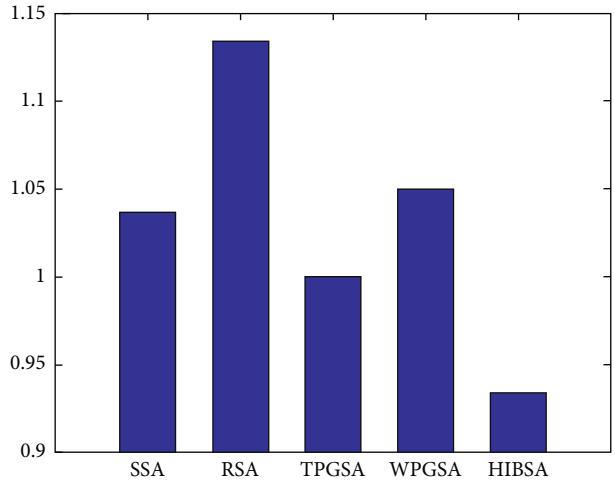

Figure 5: Comparison of average task execution time ratio of various algorithms.

algorithm for the task scheduling of each device. Some devices offload all generated tasks, while some devices have no tasks to offload. Obviously, the quartile deviation of HIBSA proposed in the paper is only 1.75, which is better than the other four algorithms.

5.2.4. Scalability Analysis. As analyzed in Section 4.4, the performance of the algorithm proposed in this paper is only related to the number N of the initialization population. However, some studies have shown that the setting of the number of initialization population should be related to the length of the problem. In this paper, the length of the problem is the product $(m \times n)$ of the number of available MEC servers and the number of IMDs. That is, with the increase of the number of servers and the number of IMDs, the number of initialization population should be increased to meet the diversity of the population.

Table 5: The sum of task weight in the first 20 time slots.

T	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SSA	312	626	851	1,254	1,485	1,718	2,128	2,440	2,850	3,172	3,492	3,733	4,063	4,303	4,544	4,849	5,089	5,322	5,634	5,874
RSA	203	316	537	650	962	1,176	1,396	1,597	1,809	1,931	2,242	2,444	2,665	2,696	2,737	3,237	3,637	3,750	3,960	4,071
TPGSA	314	547	771	1,084	1,406	1,638	1,950	2,263	2,763	3,084	3,315	3,555	3,877	4,198	4,348	4,660	4,981	5,213	5,446	5,686
WPGSA	500	725	869	1,369	1,779	1,923	2,148	2,558	2,872	3,372	3,782	3,925	4,155	4,475	4,975	5,205	5,348	5,758	5,894	6,214
HIBSA	314	747	982	1,206	1,706	2,116	2,261	2,484	2,984	3,018	3,419	3,830	4,330	4,740	4,811	4,954	5,177	5,677	5,903	6,134

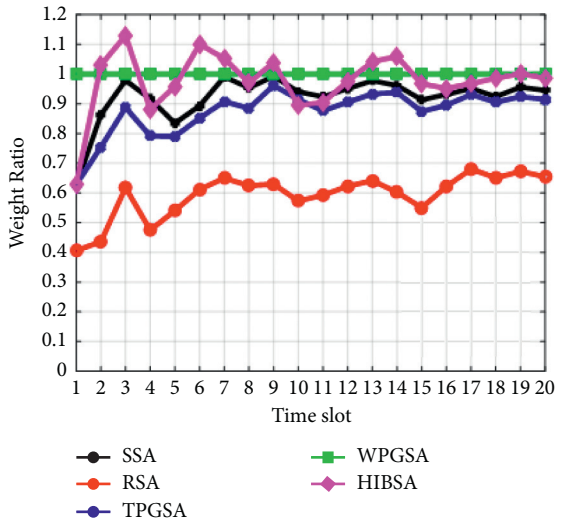

Figure 6: Comparison of task weight ratio of various algorithms of 20 time slots.

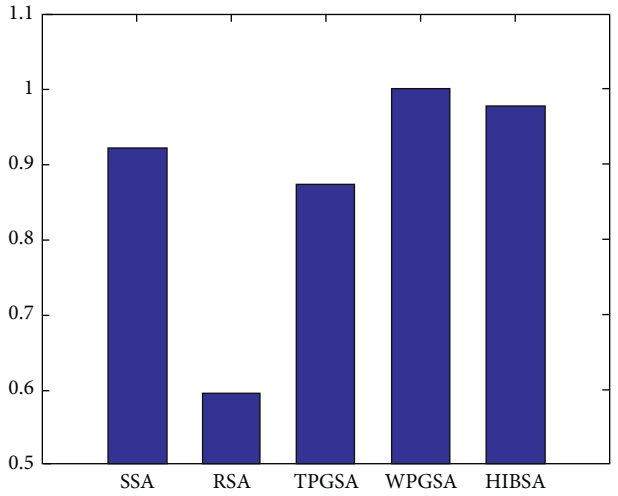

Figure 7: Comparison of average task weight ratio of various algorithms.

Table 6: The total number of scheduled tasks for 10 mobile devices in the first 20 time slots.

DEV ID	1	2	3	4	5	6	7	8	9	10	Sum
SSA	20	20	20	20	20	17	9	5	1	0	132
RSA	12	11	8	8	12	10	8	9	6	9	93
TPGSA	20	20	20	19	18	18	7	7	4	0	133
WPGSA	18	17	19	17	13	10	18	8	5	5	130
HIBSA	16	18	14	14	13	13	13	15	13	11	140

In the algorithm proposed in this paper, we adopt the method of adding diversity judgment in the iterative execution of the algorithm. If the population diversity is lower than the threshold preset, we can improve the population diversity through population diversity regulation. As shown in Figure 9, when the number of available servers is increased from 3 to 5, the number of solution space will grow from 2^{30} to 2^{50} rapidly. However, the number of initialization populations we set is all 30. The experimental results indicate that the solutions obtained by HIBSA are not

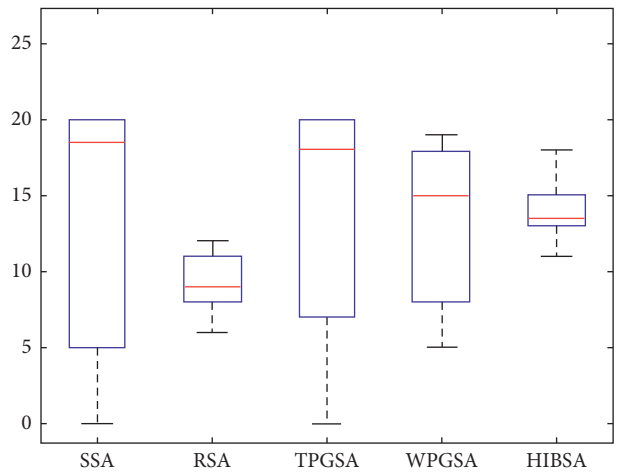

Figure 8: Comparison of the number of tasks offloaded by different algorithms.

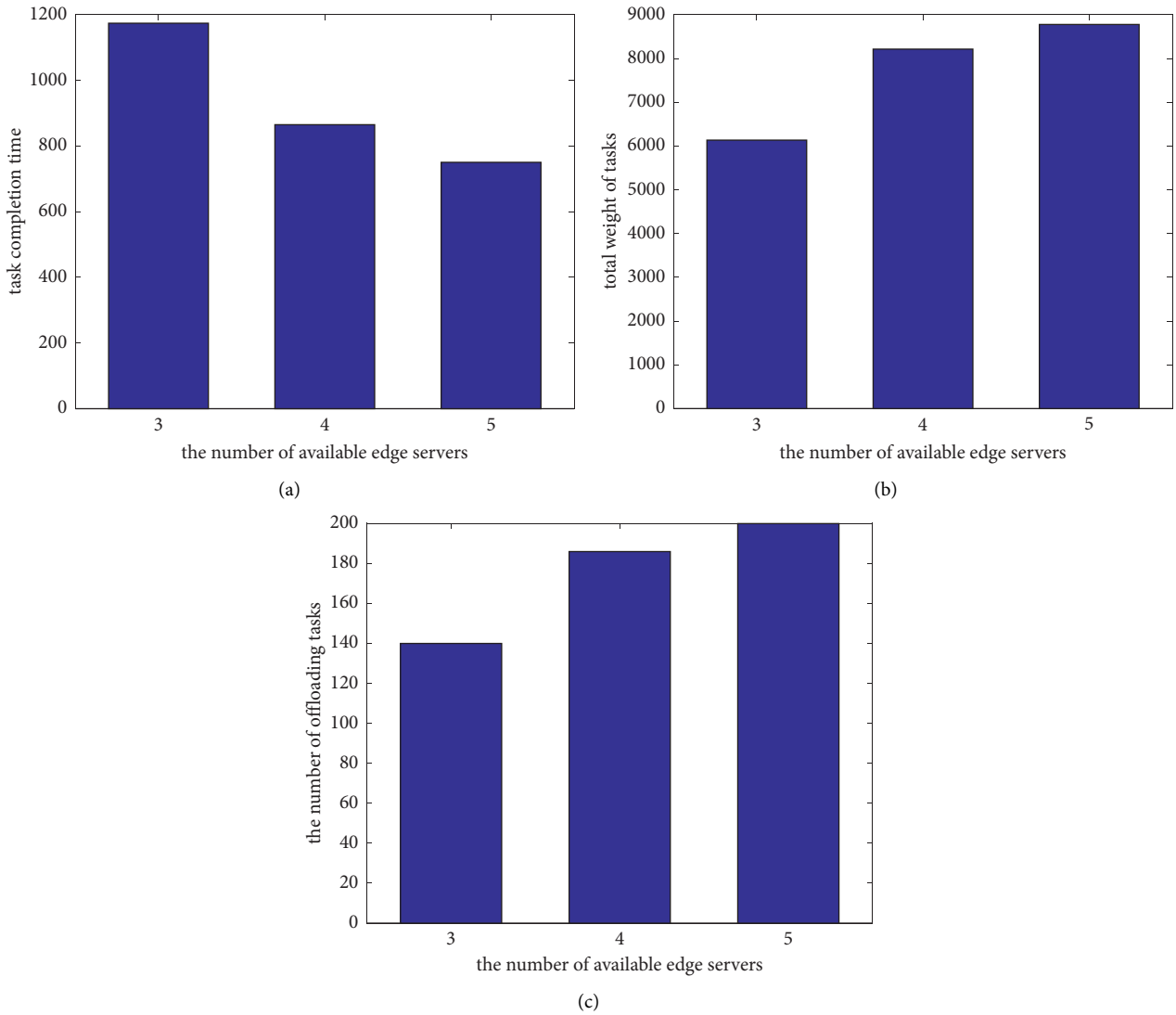

Figure 9: the scalability of the algorithm: (a) tasks execution time, (b) the total weight of tasks, and (c) the number of tasks offloading.

affected. They are significantly improved in terms of tasks execution time, the total weight of tasks, and the number of offloaded tasks, which shows the scalability of the algorithm.

6. Conclusions

Task offloading in mobile edge computing relieves the data computing pressure of local devices and central cloud by offloading data to the edge cloud, which also reduces the task execution delay caused by the lack of computing resources. In this paper, an algorithm based on hybrid immune and bat scheduling algorithm (HIBSA) is proposed to tackle the multiobjective optimization problem. Three main contributions are presented in this paper. Firstly, the proposed system model considers communication and computing resources, energy consumption of intelligent mobile devices, and weight of tasks. Secondly, the scenario that the mobile device can generate multiple tasks at the same time is considered, which is more realistic compared with most of the related works. Thirdly, the evolutionary algorithm presented combines the advantages of the bat algorithm and the immune algorithm that ensures the convergence and diversity of solutions. Finally, the practicability of the proposed algorithm is well verified by simulation. We can see from experimental results that the algorithm can meet the requirements of both the task execution time of the offloaded tasks and the weight of the completed tasks. Moreover, the algorithm has good scalability. However, the performance of the proposed algorithm can further be improved in the future. It needs to be further verified by using real scene data also.

Data Availability

The main purpose of this paper is to study the scheduling algorithm, so all the data are obtained through MATLAB simulation, not from the real scene. All data included in this study are available upon request from the corresponding author.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

This work was supported in part by the Natural Science Foundation of China under Grant nos. 61902282 and 62002263, the Doctoral Fund of Tianjin Normal University (No. 52XB1909), and the Science and Technology Development Fund of Tianjin Education Commission for Higher Education (no. JW1702).

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Hindawi
Mobile Information Systems
Volume 2021, Article ID 3702064, 10 pages
https://doi.org/10.1155/2021/3702064

Research Article

Coupling of Agricultural Product Marketing and Agricultural Economic Development Based on Big Data Analysis and "Internet+"

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Received 27 August 2021; Revised 22 September 2021; Accepted 30 September 2021; Published 18 October 2021

Academic Editor: Zhiyong Yu

In the era of "Internet+," the increase of agricultural products sales can be achieved by creating and joining e-commerce platforms. Most of the farmers in China are self-employed and cannot form an industrial scale. With the rise of "Internet+" background research, the combination of this technology and the marketing of agricultural products has become a new marketing model under the deep integration of different fields. Based on the marketing of products under the background of "Internet+" and using marketing theories, this paper reviews the development of marketing of agricultural products under the background of "Internet+," including the Internet infrastructure, the establishment of logistics system, the formation of branding, and the deep processing of agricultural products. The paper reviews the development of agricultural marketing under the background of "Internet+," including the Internet infrastructure, establishment of logistics system, branding, and deep processing of agricultural products. The marketing mode of agricultural products under the background of "Internet+" is proved, and the development of agricultural products marketing under the background of "Internet+" is discussed from various angles, and insights into how to improve it are proposed from five aspects. After excluding the influence of environmental factors through the improved three-stage SE-DEA model, the mean value of TE of comprehensive efficiency of agricultural information allocation increases from 0.773 to 0.832, the mean value of SE of scale efficiency increases from 0.844 to 0.9219, and the mean value of PTE of pure technical efficiency adjusts from 0.9087 to 0.9058. The mean value of pure technical efficiency (PTE) was adjusted from 0.9087 to 0.9058. Compared with the parametric method, DEA does not require a specific production function to be set in advance, and it is also difficult to select a suitable production function in advance for complex problems.

1. Introduction

Despite the rapid level of economic development, the world still belongs to a large agricultural country. Compared with the development of other industries, the marketing level of our agricultural products is low and cannot become an important driving force of agricultural economic development [1]. The reason for this is that China's farmers lack a high level of cultural literacy and do not have the correct concept of network marketing. Although farmers have been very familiar with the Internet, they always do not know how to correctly apply it. For this reason, farmers should establish the correct concept of Internet marketing, strengthen their own understanding and application of the Internet, use the Internet as an important way to sell agricultural products, and no longer limit the sale of agricultural products to a specific region [2]. At this time, farmers need to innovate their concepts, take the first step of Internet marketing, open stores in e-commerce platforms, learn relevant Internet marketing knowledge, and improve the sales of agricultural products. Establishing a sound network infrastructure is an important way to improve the coverage of the Internet, and an important way to use the Internet for agricultural products sales [3].

Today, most rural areas have achieved full network coverage, but some areas with more backward economic development have not yet achieved full Internet coverage [4]. The sale of agricultural products in these areas still adopts the previous low-priced bulk purchase method. For example, some agricultural products that are not suitable for preservation often rot because they cannot be sold in time, bringing certain losses to farmers. For this reason, governments at all levels should increase the investment in network infrastructure construction and improve the coverage of the Internet by means of financial subsidies, etc., so that farmers can grasp market information in time to sell their agricultural products. Professional talents are an important factor in promoting the development of agricultural economy, and Internet talents play a greater role in the process of selling agricultural products [5]. Therefore, the government should increase the training of Internet talents, organize farmers to participate in Internet skills training during the agricultural leisure period, improve farmers' Internet knowledge and practical marketing operation ability, improve farmers' Internet literacy, and provide talents to support the Internet marketing of agricultural products so that they can create corresponding Internet marketing stores on the Internet platform, upload agricultural products regularly, strengthen communication with consumers, and promote the sales of agricultural products with good and high-quality services. In the background of the new era, the Internet is developing very rapidly and applied to many fields [6]. A small number of special agricultural products in the world have seized the opportunity to innovate the development mode of agricultural products, but there are still many local special agricultural products that follow the traditional marketing model and now no longer have strong competitiveness and advantages; the traditional promotion and marketing means of special agricultural products are in a marketing dilemma [7], but the increase of total government investment amount may bring the waste of agricultural information allocation input [8]. The specific environmental factors selected in this paper include gross per capita product, total government investment amount, and the number of new rural population with higher education, among which the increase of gross per capita product and the number of new rural population with higher education can drive the utilization rate of agricultural allocation input amount and save the cost of agricultural information resource allocation, but the increase of total government investment amount may bring the waste of agricultural information allocation input.

With the rapid development of the economy and the continuous innovation of Internet technology, the marketing mode of the world's agricultural products has undergone great changes in recent years. Some agricultural products with local characteristics have started to attract the attention of consumers outside the region, and promoting the development of special agricultural products will become an inevitable trend of economic development [9]. In this paper, we analyze the current situation of marketing of characteristic agricultural products under the background of "Internet+" and some of the difficulties faced at present, study the development history and marketing path of marketing of characteristic agricultural products, and explore the innovation mode of marketing of characteristic agricultural products so as to provide some reference for the marketing of characteristic agricultural products under the environment of high-speed development of Internet. However, due to the different realities in different places, the lag of various links from production and operation of agricultural products to consumer purchase, the traditional concept of marketing, compared with the marketing concept of "Internet+" agricultural products, has not been able to play the greatest superiority. The problems of agricultural products marketing under the background of "Internet+" studied in this paper include low coverage of Internet infrastructure, inadequate construction of logistics system, asymmetry of product marketing information, relatively late branding construction, and lack of marketing awareness under the background of "Internet+." In addition, we propose targeted marketing strategies under the background of "Internet+."

This has theoretical significance for the research of marketing strategies of agricultural products in different regions in the world at the present stage, and at the same time, due to the development of this study, each region can use different methods based on its own characteristics to conduct in-depth Internet marketing exploration for the special agricultural products in the region, which can also provide reference opinions for such research in different regions. Agricultural marketing refers to the marketing process of agricultural products, according to the subject—the operator—and the producer's independent dynamic behavior, coupled with interference factors, the targeted marketing activities, so as to meet the transformation of crops from goods to commodities of commercial properties, so that agricultural products are given commercial value, to meet the needs of society for agricultural products, so as to get more economic added value of a kind of activity. It is different from the traditional marketing, which is dominated by production conditions.

2. Related Work

The development of agricultural industry is inseparable from the marketing effect of agricultural products, which directly determines whether the overall industrial chain of agricultural products is well developed or not, and is also the embodiment of the marketing value of agricultural products [10]. The background of "Internet+" technology has developed with the rise of online shopping. This consumption channel chosen by consumers has accelerated the speed of commodity circulation, and also made the competition among merchants in various regions more transparent and fierce. Farmers should fully grasp the business opportunities, use the "Internet+" integration of technology platform for development, sales of their own agricultural products, so that the sales of agricultural products to improve. This is not only the result of integrating modern technology, but also the sublimation of modern marketing concept [11]. The added value of agricultural products can be actively

increased, and the marketing efficiency of production and distribution can reach a level unmatched by the traditional marketing mode so that the production and operation methods of agricultural products can be improved and the market share of different agricultural products can be increased [12]. The accelerated development of the agricultural industry is not only conducive to improving the income and living standards of the majority of farmers, but also has practical significance in reducing the unbalanced economy of various regions in this context.

At present, the research on the development of agricultural marketing under the perspective of "Internet+" is in the initial stage at home and abroad, and certain results have been achieved. The current situation of online marketing of agricultural products in the world and the experience of online marketing of agricultural products in other countries are fully integrated [13]. In addition, researchers also discuss the logistics and distribution system of agricultural products marketing and follow the development of the Internet, in order to promote the rapid development of the world's agricultural products online marketing [14]. At the same time, in the context of the "Internet+" era, scholars have analyzed the impact of the "Internet+" model on the world's traditional agricultural marketing model and the domestic market economy [15]. The research results of the scholars have the characteristics of being close to the actual and practical sources for the online marketing of agricultural products in the world, which are more foreseeable and pioneering for the development of agricultural marketing under the premise of "Internet+", and also provide more accurate reference and reference for the marketing of agricultural products [16]. Our government departments at all levels also actively support the marketing of agricultural products, and continuously guide and promote the development of the agricultural industry chain. However, due to the vast territory, the natural resources and production conditions of agricultural products vary from place to place, so the characteristics of agricultural products vary from place to place. However, the quality of agricultural products in some regions is good, but there is no good marketing strategy to expand their popularity, resulting in the mismatch between production and marketing [17]. There is an urgent need to study and set up a reasonable marketing model to broaden the sales channels of agricultural products. It is necessary to integrate the regional and seasonal factors to promote the economic prosperity of agricultural products under the unique natural resources of each region and to upgrade the industrial chain of agricultural products as soon as possible.

In recent years, under the guidance of the relevant departments of logistics system construction, the state has introduced a series of development plans to accelerate the construction of logistics facilities such as storage, transportation, and processing of agricultural products in the world and to establish a sound logistics service system [18]. The development plan requires emphasis on providing guarantee for the improvement of logistics marketing efficiency of agricultural products in the world. However, regarding the logistics system of agricultural products in some areas, especially in Guangxi, Shanxi, Gansu, and other agricultural products planted in a wide area, but for the weak economic base of the part, whether from the equipment, technology, or labor, frozen storage and other aspects, there is still room for improvement. Undertaking the key logistics system of the circulation of important agricultural products still needs to improve and enhance the part of the construction [19]. This will directly affect the damage rate of agricultural products, especially fresh products [20]. The different natural resources in each region have given birth to excellent crop varieties [21]. Whether it is vegetables, fruits, or rice, all of them have geographical advantages, and some of them have already occupied a certain position in consumers' heart, such as Jiangsu Yangshan peach and Shandong chestnut, which have been awarded with geographical indications. However, the marketing method of brand establishment and maintenance is less, and at present, agricultural products still take the geographical location of each place as the main symbol, and the formation and development of brands are not synchronized among different agricultural products producers.

3. "Internet+" Perspective of Agricultural Marketing Information Resource Allocation Marketing Efficiency

3.1. Nonparametric Analysis of the Efficiency of Configuration Marketing. When studying the marketing efficiency problem of agricultural information resource utilization, there are two general analysis methods, nonparametric analysis (DEA) and parametric analysis (SFA), each of which has advantages and disadvantages in use. The parametric analysis method (SFA) has a greater advantage in dealing with the marketing efficiency problem of multiple inputs corresponding to one output [22–24]. However, agricultural information resource allocation marketing efficiency problems generally need to solve the correspondence between multiple inputs and multiple outputs, which cannot be measured simply by using the parametric analysis method. Compared with the parametric method, DEA does not require a specific production function to be set in advance, and it is also difficult to select a suitable production function in advance for complex problems and directly apply the output and input data of agricultural information resource allocation decision subjects to the DEA method; it can measure the relative marketing efficiency values among decision units, eliminating the adverse effects of many human subjective factors.

DEA analysis, whose full name is Data Envelopment Analysis, is a nonparametric analysis method studied through the integrated use of mathematical statistics, management science, and operations research, as shown in Figure 1. The method can use the results of the evaluation of the marketing efficiency of multiple-output and multiple-input systems to represent the marketing efficiency values of agricultural information resources allocation, and also to analyze the relative marketing efficiency values among the decision units. Before determining the input-output

effectiveness, the production frontier surface is first found, which can be determined using linear programming. Then, each decision unit is mapped, and the relative effectiveness of each decision unit is evaluated by comparing the distance between each decision unit and the production frontier surface (see Figure 1).

The scale of the input and output indicators also does not affect the measurement results, so DEA is a good method to judge the validity between multiple inputs and multiple outputs. Assuming that there are n decision units, each decision unit has s different outputs and m different inputs, the input of the ith input and the jth decision unit can be represented by x_i, and the output of the rth output and the jth decision unit can be represented by y_i, the basic input-oriented DEA analysis model (CCR) is

$$\begin{aligned} V_d &= A^{\min}, \\ \sum_{i=1}^{n} V_i x_i &= \beta_i, \\ \sum_{i=1}^{n} V_i y_i &= \alpha_i. \end{aligned} \tag{1}$$

Andersen (1993) created the SE-DEA model of supermarketing efficiency. Compared with the traditional DEA model, SE-DEA uses a reference set that does not include the evaluated decision units; that is, the inputs and outputs of the evaluated decision units are expressed by linear combinations of the inputs and outputs of other decision units so that the evaluation results can still be measured with increasing returns to scale. At the same time, SE-DEA can rank or classify all decision units that satisfy the effective production frontier. Coupled with the ability to redundantly analyze slack variables, specific information on specific resources with high marketing efficiency can be identified in cities with high-resource utilization, providing more effective information to guide resource allocation in other cities. The supermarketing efficiency SE-DEA model is shown as follows:

$$\begin{aligned} \sum_{i=1}^{n} V_i y_i - s^{+} &= \alpha_{io}, \\ \sum_{i=1}^{n} V_i x_i - s^{-} &= \beta_{io}, \\ V_d &= \alpha_i - \beta_i. \end{aligned} \tag{2}$$

The construction of the evaluation index system of any research object requires scientific basis and systematic and thorough consideration. The application theory of agricultural information science recognized by the industry is the theoretical basis for constructing evaluation indexes of agricultural information resource allocation and marketing efficiency. The construction of agricultural information resource allocation indexes should not only meet the logic of agricultural information science application, but also fully consider the development of agricultural information technology and truly and accurately reflect the fundamental problem of marketing efficiency differences in various regions. Agricultural information resource allocation involves multiple inputs and outputs, and is a complex systemic issue that requires coordinated and common assistance from various aspects such as financial investment in agricultural informatization, human and material investment in agricultural operation, agricultural information technology development and application, and agricultural information infrastructure construction. Research on the efficiency of agricultural information resources configuration marketing should not only consider the configuration and utilization of local municipalities, but also grasp the important guiding policies of agricultural informatization to improve the accuracy of configuration and utilization measurement.

3.2. Marketing of Agricultural Products. Agricultural marketing refers to the marketing process of agricultural products, according to the subject—the operator—and the producer's independent dynamic behavior, coupled with interference factors, the targeted marketing activities, so as to meet the transformation of crops from goods to commodities of commercial properties, so that agricultural products are given commercial value, to meet the needs of society for agricultural products, so as to get more economic added value of a kind of activity. It is different from the traditional marketing, which is dominated by production conditions. Marketing of agricultural products also refers to a marketing method in which agricultural producers and operators ensure the efficient service of the whole industrial chain based on the market law and the characteristics of vegetables and fruits produced in the specific situation and the different local regions and seasons, so that the sales of agricultural products can be increased. This is a marketing method to grasp the overall demand of consumers and to meet the potential orientation of the market, actively seek the sales effect and cope with anti-interference.

Agricultural information resource allocation assessment indicators need to be as comprehensive as possible under the premise of feasibility in order to constitute a basic and operable evaluation indicator system. It is not the case that the more indicators selected to assess the allocation marketing efficiency of agricultural information resources, the better; too many indicators are likely to make the system overfitted and the calculated results to guide the operability value to be lower, as shown in Figure 2. In the process of configuration marketing efficiency evaluation, some factors are incidental, small amount, short duration, and no important influence, and these factors can be blocked out. At the same time, the evaluation indexes selected in this paper need to be tested in practice, and their operability can be corroborated by practical cases. The development of agricultural informatization has not stopped since the 1980s, but with the adjustment of agricultural informatization policy, innovation of information technology, and change of agricultural economic development ideas, the allocation of agricultural information resources needs to be adjusted in different ways according to the current situation.

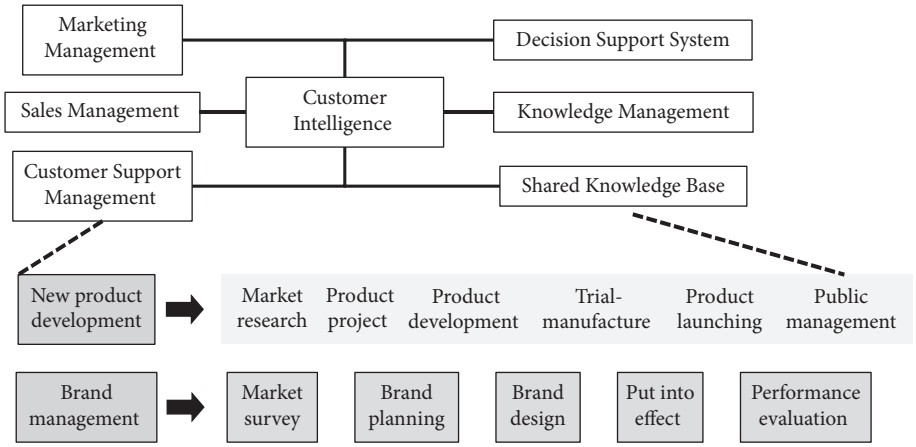

Figure 1: Marketing analysis theory based on mathematical statistics.

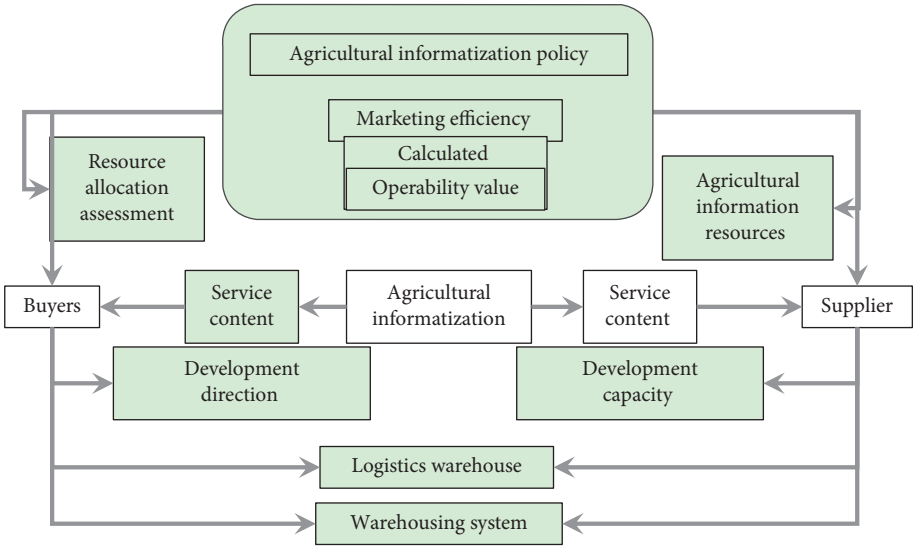

Figure 2: Indicators of marketing efficiency of agricultural information resources allocation.

Agricultural information resource allocation evaluation indexes need to be adjusted at different stages according to the development direction and development capacity of informatization, and only in this way can we continuously improve the efficiency of agricultural information resource allocation and marketing, and more practically and feasibly contribute to the development of agricultural informatization (see Figure 2).

The concept of "Internet+" is not just a simple superimposition of concepts, nor is it a superficial association between agricultural marketing and "Internet+," but a deep organic integration of "Internet+" with the overall. It is a deep organic integration of "Internet+" and overall agricultural marketing, creating more scientific and efficient modern agricultural marketing means and methods. It is the integration of the traditional agricultural market into the new agricultural marketing methods, and proposes a reasonable, fast, and shared new marketing approach. It can change the traditional agricultural marketing means, pursue the development of production and market expansion more, quickly enhance the new agricultural marketing methods, and promote the agricultural industry to promote the steady progress of modern agriculture. The combination of "Internet+" and agricultural marketing is divided into different stages to carry out. In the primary stage, we can simply integrate the platform sales technology of e-commerce into the marketing of agricultural products, reflecting the characteristics of its network sales; in the second stage, the concept of the Internet will be fully penetrated into the marketing of agricultural products; in the third stage, the stage of comprehensive integration, more detailed

guidance on the whole industrial chain of agricultural products, and the service concept of consumers, to realize the integrated development of modern agriculture.

4. Results and Analysis

In order to analyze in more detail the main influencing factors of agricultural information resource allocation marketing efficiency in 10 prefecture-level cities, we combine the evaluation indexes of agricultural information resource allocation marketing efficiency established in the previous chapter based on scientific, operability, and dynamics, and establish the explanatory variables of the influencing factors of Tobit model, including the number of cell phones in 100 rural residents' households, the population coverage rate of digital TV in rural residents, the number of rural residents' 100 Internet bandwidth access, the number of agricultural information-related websites, and the number of cultural stations for rural residents, as shown in Figure 3. The agricultural sector has also formed a special website for the sale of agricultural products. The data in this chapter are also derived from Internet information. At present, although the deep processing of agricultural products has attracted the attention of various production and processing enterprises, the systematization required is high, the software and hardware equipment for professional production and processing are not well implemented, and the unfavorable factors in the processing process may also affect the quality of agricultural products. To a certain extent, this will pull the marketing system and competitiveness of agricultural products to a weaker side. In the field of processing, in terms of the current situation of deep processing, the industrial chain and market radiation ability are relatively weak, which will affect the size of the added value of agricultural products. The self-built enterprise refers to the self-built platform of the agricultural production enterprises based on their production technology and marketing methods. By perfecting their own sales chain, they can develop and cooperate from their own platform and sell agricultural products. For example, Gansu Jurong Company has built its own "Jurong.com," and Jiangxi Nanfeng Fruit Trade has built its own e-commerce platform to carry out one-stop services. Some agricultural production bases also build platforms for agricultural products, but such enterprises build their own way, mainly by commissioning other large enterprises to complete (see Figure 3).

Through Tobit regression analysis, as shown in Figure 4, the degree of influence of these five variables on the allocation marketing efficiency of agricultural information resources was measured, among which the number of cell phones per 100 rural residents and the amount of Internet bandwidth access per 100 rural residents were significant below the level of 0.01 (Prob. < 0.01), and the degree of influence of the remaining items was measured not very significant, but also had a correspondingly positive effect on the allocation marketing. The remaining items are not significant, but they also have a positive effect on the allocation of marketing efficiency. Among the five variables mentioned above, the number of cell phones and the amount

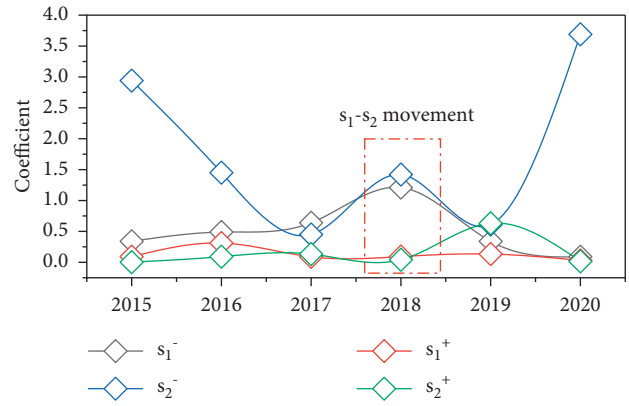

Figure 3: Impact of variables in Tobit model.

of Internet bandwidth access are the most important ones in terms of allocative marketing efficiency. Government guidance refers to the provision of enterprise services such as information-based production and marketing of the whole industry chain to the marketing platform of agricultural products in the mode of government services. The agricultural sector has also formed a special website for the sale of agricultural products. It can help and support the small and micro agricultural products production enterprises in each region to occupy a favorable position in the operation and marketing activities of agricultural products. This kind of platform is a public welfare project of the government, and the cost is also borne by the government. At present, the more commonly used authoritative platforms include "National Public Service Platform for Agricultural Products Business Information," "Planting and Breeding Agricultural Products Traceability System Platform," and "National Public Information Platform for Agricultural Products Quality and Safety." Through the discovery of invisible customer groups, more and more people understand agricultural products. Farmers can make use of various modes of the Internet to advertise their agricultural products. By creating web pages dedicated to agricultural products, fictional animated stories about agricultural products, designing special icons of agricultural products, etc., and adding pictures, videos, and relevant product proofs to them to make consumers understand more clearly and minimize the problems arising from asymmetric information about agricultural products between farmers and consumers. The promotion of agricultural product information and outstanding sales volume cannot be achieved without the Internet (see Figure 4).

The coefficients of factors such as the number of cell phones per 100 rural households, Internet bandwidth per 100 rural households, digital TV population coverage of rural residents, and the number of agricultural information-related websites are positive, indicating that agricultural information infrastructure construction factors have a significant positive effect on information allocation marketing efficiency in general, which is consistent with the guiding goal of promoting information service system construction in agricultural informatization, and the allocation of agricultural information resources should be adhered to. Quantity and quality should be given equal

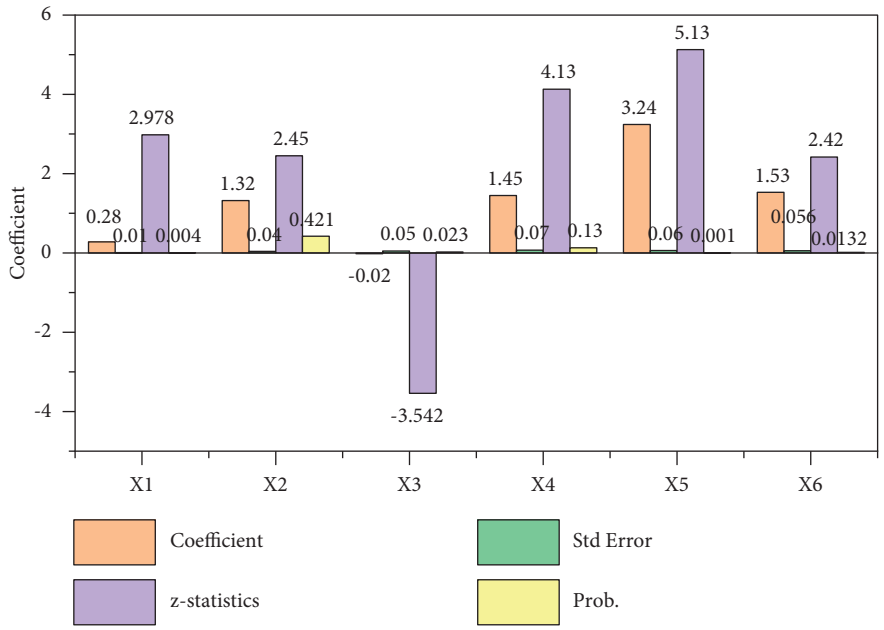

Figure 4: Results of Tobit model.

importance to development, and the construction of information service system needs to be vigorously promoted by government-led efforts to help support the development of enterprises, talents, and technologies that carry information services, and solve the problems of coverage, acceptance and the last mile in information services. Each increase of 1 unit in the number of cell phones will increase the value of comprehensive marketing efficiency of agricultural information resource allocation by 0.01 units, and each increase of 1 unit in the amount of Internet bandwidth access will increase the value of comprehensive marketing efficiency of agricultural information resource allocation by 0.04 units, as shown in Figure 5. Taken together, the increase in the amount of these positively correlated inputs will continue to promote the improvement of comprehensive marketing efficiency until a certain optimal scale level is achieved. The continuous development of e-commerce has driven a change in the marketing model of agricultural products to a certain proportion of online sales. Farmers are flocking to participate in online sales, tapping more invisible customers and giving agricultural products access to a wider sales market. Because the price of the same product is lower and more affordable in offline stores and online platforms than in online platforms, it is more in line with consumer demand. Therefore, in the context of "Internet+," the pricing on the online platform also limits the sales volume of agricultural products. With the decline in net income, farmers have improved their production technology by innovating in terms of planting techniques in order not to lose money. In response, the fierce competitive environment is also conducive to stimulating related companies to play the game, thus leading to the progress of agriculture as a whole (see Figure 5).

The Tobit measurement coefficient of the number of rural residential cultural stations on the comprehensive marketing efficiency is negative, but the importance of rural residential cultural stations in promoting the marketing

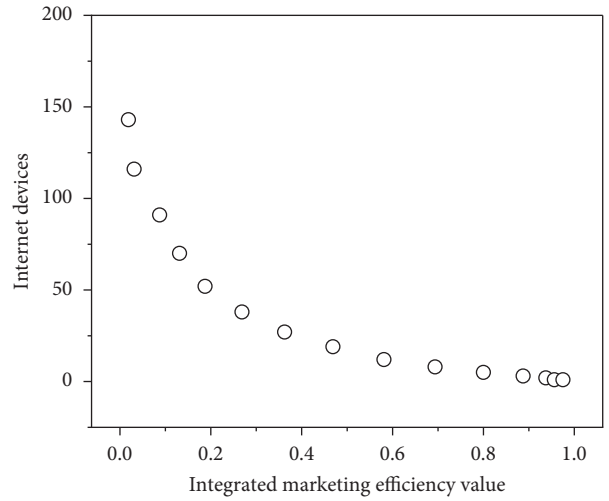

Figure 5: Correlation between the integrated marketing efficiency value of agricultural information resource allocation and the number of internet devices.

efficiency of agricultural information resource allocation cannot be denied in its entirety, nor is it one-sided to say that by reducing the number of rural residential cultural stations, the comprehensive marketing efficiency of 0.0004 units can be improved, as shown in Figure 6. The reason for this is that the focus of the current use of cultural stations for rural residents has shifted, and they may no longer be single agricultural information and cultural stations, but may also be used for information dissemination in other industries and for entertainment in rural areas. "Visual agriculture" refers to the use of the Internet, the Internet of Things, and modern video technology to show consumers the growth process of crops or livestock, so that they can buy quality products with confidence, that is, a kind of visible

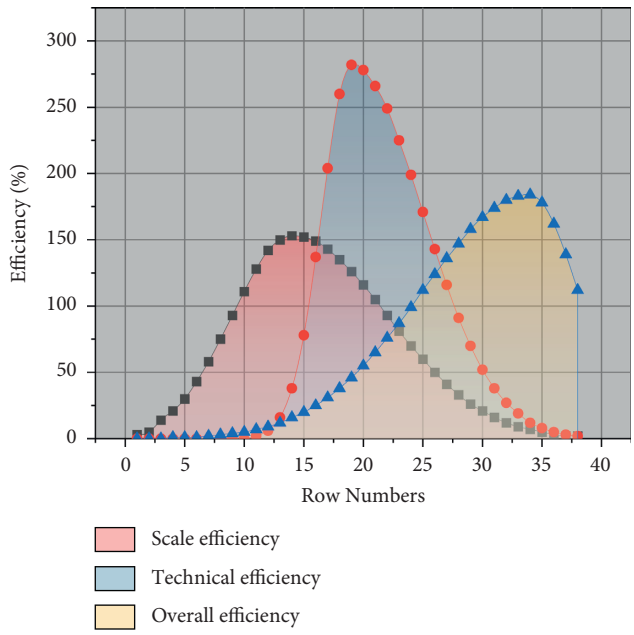

Figure 6: Effect of the number of cultural stations for rural residents on the efficiency of integrated marketing.

agriculture. This model is to let farmers reveal all their planting and operating behaviors in the sunlight, so that farmers' management can be further improved and bad behaviors can be restrained. Agricultural products can be advertised by hiring a professional filming team and broadcasted in commercial plazas with high traffic flow as well as on various Internet media. Consumers can view the vegetables and fruits planted in the base through Internet video, and also enjoy the joy of raising livestock in the cloud. No matter when and where they are, they can see the growth dynamics of crops or livestock, fertilization, and feeding through video or pictures, so that they can buy healthy products without additives and pollution without worries (see Figure 6).

Because most consumers learn about the agricultural products they need on e-commerce or Internet platforms, more and more farmers are leaving the opportunity to showcase and promote their agricultural products to e-commerce and Internet platforms. In this way, consumers can buy the agricultural products they need without having to leave home. The Ali platform has opened up new sales channels for agricultural products with e-commerce to the countryside, creating a village e-commerce system in collaboration with relevant departments, deepening the field of agricultural products e-commerce, and solving the problem of difficult sales and transportation of agricultural products. The most important thing for the development of agricultural products on the Internet is the means of network marketing, the Internet is developing rapidly, but the technology is still immature, and there is a serious lack of marketing talents in network; various relevant departments should increase rural education capital, improve farmers' awareness of agricultural production and marketing efficiency, provide farmers with knowledge and technical guidance, so as to enhance farmers' network, business and marketing management techniques, cultivate the technology engaged in agricultural products network Talent, to provide a strong guarantee for the world's agricultural products network marketing. At the same time, the improved DEA model also conducts superefficiency analysis for cities in the efficiency frontier side of agricultural information resource allocation and provides a more in-depth interpretation of each city's decision-making unit, as shown in Figure 7, in which the superefficiency value of City reaches 1.6896, and rank 2nd to 3rd, and the superefficiency analysis can indicate that the financial investment, agricultural information service input, and agricultural information. The superefficiency analysis can show that these four cities can still maintain their relative efficiency by increasing their financial input, agricultural information service input, and agricultural information construction input according to the ratio of 68.96%, 39.86%, 25.38%, and 21.75% (see Figure 7).

With the scale marketing efficiency SE and pure technical marketing efficiency PTE as the axes and the full evaluation value (0.9058, 0.9219) as the critical point, four types of cities are divided to show the allocation of agricultural information resources in northern Shaanxi, southern Shaanxi, and central, as shown in Figure 8. The first category in the upper right corner of the figure is the "double-high" cities with scale marketing efficiency and pure technical marketing efficiency above the critical value, including Xi'an, Yulin, Yan'an, and Tongchuan, which have less room to improve the marketing efficiency of agricultural information resource allocation; the second category is the second quadrant with the critical point as the origin, which has high-scale marketing efficiency but low pure technical marketing efficiency. This type of cities includes Xianyang and Weinan, with PTEs of 0.739 and 0.801, respectively, which have more room for improvement; the third category is the third quadrant with the origin of the critical point, where the scale marketing efficiency and the pure technical marketing efficiency are double-bottom cities, such as Ankang, which need to be adjusted from the configuration scale and technical management level in order to improve comprehensively; the fourth category is the last quadrant with the origin of the critical point, where the scale marketing efficiency is high but the technical marketing efficiency is low. High-low cities with high pure technical marketing efficiency but bottom scale marketing efficiency, including Baoji, Hanzhong, and Shangluo, these cities should improve in the configuration scale strategy, increase the coverage of agricultural informatization, and improve in the scale efficiency of agricultural information resource allocation (see Figure 8).

The efficiency values estimated by the BCC model in the improved DEA method belong to discrete distribution data truncated between 0 and 1. If the efficiency values of the improved three-stage DEA are interpreted by regression using the traditional OLS least squares method, they are prone to large biases in the estimation of agricultural information input parameters. The Tobit model is also an extension of the traditional Probit model, in which the explanatory quantity can be "unrestricted" when the value of the explanatory variable is greater than 0. This paper

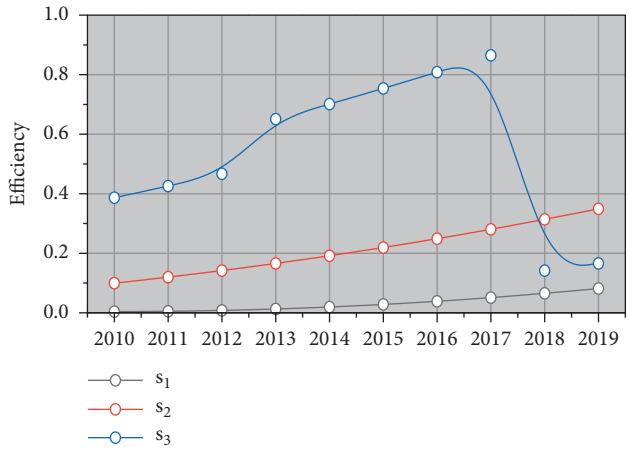

Figure 7: Variation of the relationship between entities E and R.

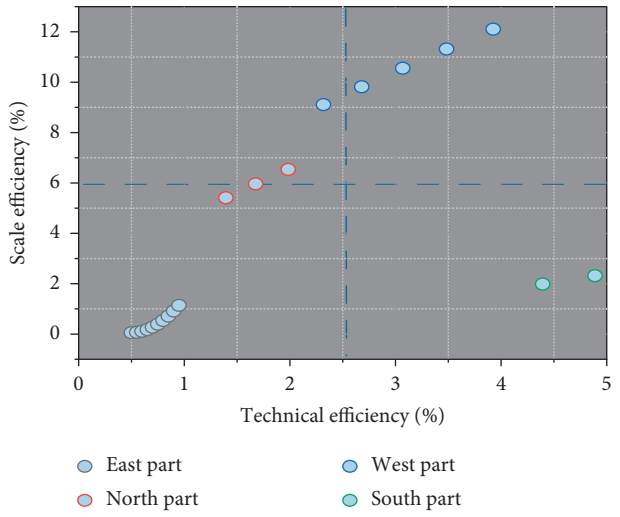

Figure 8: Configuration efficiency distribution quadrant.

constructs a Tobit regression model to analyze the impact of agricultural information resource allocation efficiency based on the input parameters of agricultural information resource allocation. The specific environmental factors selected in this paper include gross per capita product, total government investment amount, and the number of new rural population with higher education, among which the increase of gross per capita product and the number of new rural population with higher education can drive the utilization rate of agricultural allocation input amount and save the cost of agricultural information resource allocation, but the increase of total government investment amount may bring the waste of agricultural information allocation input. We hope that we can refer to the positive and negative correlation reasons of specific environmental factors to adjust and help to improve the allocation efficiency more.

5. Conclusion

This paper reviews the development of agricultural marketing under the background of "Internet+," including the Internet infrastructure, the establishment of logistics system, branding, and deep processing of agricultural products. The marketing mode of agricultural products under the background of "Internet+" is proved, and the ways of agricultural marketing development under the background of "Internet+" are discussed from various angles, and insights into how to improve them are proposed from five aspects. The combination of "Internet+" background and agricultural marketing is of great practical significance to enhance the logistics and brand reputation of agricultural products, strengthen the construction of network platform infrastructure, and further improve the system of agricultural marketing in the world. Based on the Tobit model, this paper establishes a detailed analysis of the positive and negative effects of input factors on agricultural allocation efficiency, such as the number of cell phones per 100 rural households, the population coverage rate of digital TV for rural residents, the amount of Internet bandwidth access per 100 rural households, the number of agricultural information-related websites, and the number of cultural stations for rural residents. Comprehensive Tobit model measurement results analysis, cell phone, Internet bandwidth access, and other factors have a positive effect on the comprehensive efficiency; the role of the number of cultural stations for rural residents has a negative effect on the comprehensive efficiency. The results of the traditional DEA model measuring the efficiency of agricultural information resource allocation have large errors. After excluding the influence of environmental factors through the improved three-stage SE-DEA model, the mean value of TE of agricultural information allocation increases from 0.773 to 0.832, the mean value of SE of scale efficiency increases from 0.844 to 0.9219, and the mean value of PTE of pure technical efficiency increases from 0.9087. In the future, we would improve their production technology by innovating in terms of planting techniques in order not to lose money.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Hindawi
Mobile Information Systems
Volume 2021, Article ID 2547648, 14 pages
https://doi.org/10.1155/2021/2547648

Research Article

An Empirical Study on the Countermeasures of Implementing 5G Multimedia Network Technology in College Education

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Received 1 September 2021; Revised 22 September 2021; Accepted 28 September 2021; Published 13 October 2021

Academic Editor: Zhiyong Yu

Aiming at the problem of 5G multimedia heterogeneous multimodal network representation learning, this paper proposes a collaborative multimodal heterogeneous network representation learning method based on attention mechanism. This method learns different representations for nodes based on heterogeneous network structure information and multimodal content and designs an attention mechanism to learn weights for different representations to fuse them to obtain robust node representations. Combining the general process of exploring the college physical education model and the characteristics of the multimedia network classroom environment, this article constructs the process of exploring the college physical education teaching model of the multimedia network classroom. Through the research and practice of the inquiry college physical education teaching model in the multimedia network classroom, it is verified that the implementation of the inquiry college physical education teaching in the multimedia network classroom can effectively influence and increase the students' interest in learning and stimulate the students' inner learning motivation. Through the guidance and training of teachers, a variety of disciplines can be used to carry out college physical education in multimedia network classrooms, so that the integration between courses can be truly realized, with the aim that all courses can share the excellent results brought by the development of modern education technology. More educators understand, accept, and participate in the practice of college physical education based on multimedia network classrooms and better serve the education of college physical education. The construction of the college physical education evaluation system should be combined with the characteristics of the 5G multimedia network era. The evaluation process includes data collection, data analysis, result output, and result feedback. Each link is an indispensable part of the college physical education evaluation process. Based on the relevant knowledge of the 5G multimedia network, the evaluation indicators determined in this study can basically reflect the various elements of the physical education process in colleges and universities. The distribution of index weight coefficients is more scientific and reasonable. Compared with the current system, the college physical education evaluation system constructed by exploration has a certain degree of objectivity and scientificity. Therefore, it is feasible to apply the 5G multimedia network to the evaluation of college physical education.

1. Introduction

With the development of the global economy, science and technology have achieved unprecedented development under the impetus of this economic wave [1]. First, computer information technology has been widely popularized and applied, which then led to the emergence and development of Internet technology, as shown in the background of the previous topic selection. The Internet has such a large audience in our country, so it can be seen that human society has entered a new era of knowledge and network. The popularization and application of the Internet and the development and application of new multimedia technologies have provided a new way of modern college physical education [2]. The combination of the two has given rise to the multimedia network college physical education teaching technology, which serves as a multimedia network college physical education teaching. The carrier of technology in the

process of college physical education can be called a multimedia network college physical education platform. Multimedia network college physical education is open and interactive at the same time, and these are incomparable to traditional college physical education. It is known for its rich resources and powerful functions and emphasizes that students are the main body, so as to run through the entire process of physical education in colleges and universities. The multimedia network college sports teaching platform provides students with a more intuitive and visualized learning platform with real-time interaction [3]. All these are in line with the direction of the development and reform of physical education in modern education colleges.

Through the investigation and analysis of the latest information released by relevant authoritative websites on the Internet, it is found that the construction and development level of my country's multimedia network college sports teaching platform is obviously unevenly distributed [4]. The construction and development of the multimedia network college physical education platform in the economically developed eastern and central regions and some colleges and universities have begun to take shape, while some economically underdeveloped western regions and most colleges and universities' multimedia network college physical education platforms are still in the early stages of exploration. In the development and construction, there are still many regions and universities that have not developed and constructed the multimedia network college sports teaching platform. Although many colleges and universities have their own campus networks, they only use their campus websites as information publishing and downloading platforms and do not have a complete set of multimedia network college physical education teaching systems [5]. However, in the surveyed colleges and universities that have applied the multimedia network college physical education platform, the use of the multimedia network college physical education platform is basically limited to the main subjects of the colleges and universities, and as some nonsports special subject colleges, the part used in college physical education in colleges and universities is very few.

Aiming at the heterogeneity, sparsity, and multimodality of 5G multimedia network data, a multimodal heterogeneous network representation learning model based on attention collaboration is proposed. The model uses metapaths to capture hidden structural information and multimodal content information in heterogeneous multimodal networks and learns node representations based on structural information and content information, respectively. We propose a collaborative framework based on the attention mechanism to fuse the structural representation and content representation of nodes to obtain a robust node representation. Based on the theoretical basis of exploring the teaching mode of college physical education in the multimedia network classroom, this article analyzes the characteristics of exploring the teaching mode of college physical education and the multimedia network classroom. Combining the general process of exploring the college physical education model and following the design principles, this article constructs a flow chart of college physical education teaching design that explores the college physical education model of a multimedia network classroom and analyzes and elaborates the flow chart in detail. Under the guidance of the teaching principles of college physical education and the design process of college physical education, the whole process of college physical education implementation is demonstrated with college physical education teaching cases. The construction of the college physical education evaluation system should be combined with the characteristics of the 5G multimedia network era. The evaluation process includes four major links: data collection, data analysis, result output, and result feedback. Data collection must be comprehensive, data analysis methods must be scientific, and the output of the results must be accurate. The feedback of the results should be disclosed in time. Based on the relevant knowledge of the 5G multimedia network, the evaluation indicators determined in this study can basically reflect the various elements of the physical education process in colleges and universities.

2. Related Work

The United States is recognized as the earliest and most advanced country in the development of multimedia network college physical education teaching and the most extensive use of multimedia college physical education teaching [6]. According to a survey conducted by the U.S. Federal Department of Education on the physical education teaching of multimedia networked colleges and universities in American secondary education institutions, 1,690 of the 5,020 primary and secondary schools in the United States provide physical education courses in online colleges and universities. This data accounts for 34% of the total number of primary and secondary schools. Approximately 660,000 students have registered and are willing to participate in multimedia network college physical education teaching. This data accounts for approximately 11.6% of the total number of students in primary and secondary schools (approximately 14.34 million) [7]. Regarding college physical education teaching, schools that use multimedia college physical education, such as California Virtual University, Michigan Virtual University, American Electronic University Network, and Jones International University as representative universities, even completely abandon the traditional college physical education concept; all are computer and server.

Early foreign universities that used network technology to teach physical education in colleges include Stanford University in the United States and the University of Southern Queensland in Australia. The continuous deepening of the application of network technology to college physical education has gradually become an important component of college physical education and at the same time has become the direction of the modern development of college physical education. At present, the research results of college physical education in foreign colleges and universities under the network environment, as well as the research of college physical education teaching models, are still in the initial stage. However, with the continuous

development of network technology and the positive improvement of college physical education courses, the use of network technology in college physical education will be effectively promoted, and related college physical education research will also be continuously strengthened.

In terms of the application of network technology to college physical education in colleges and universities, the Massachusetts Institute of Technology in the United States used electronic sports teaching materials in college physical education as early as 2001 and passed the college physical education content of various sports in college physical education [8]. It also builds a network platform for college physical education assessment, which facilitates students to remotely learn through the Internet in a timely manner, assists in sports training and other college physical education contents, and realizes functions such as online examinations, which fully reflects the modern technology of college physical education. Features realize the diversification of college physical education forms and greatly improve the flexibility of college physical education.

Relevant scholars analyzed the application of modern educational technology in college physical education by using the literature method and logical analysis method and pointed out that modern computer network technology provides a brand-new platform for college physical education in colleges and universities [9]. This kind of platform is used in college physical education. Application is the inheritance and development of traditional college physical education. The promotion of new multimedia network technology in college physical education not only promotes the transformation of college teachers' concepts of college physical education but also optimizes college physical teaching theory, college physical teaching methods, college physical teaching evaluation, and technical and tactical college physical teaching. Relevant scholars summarized the characteristics of physical education in schools and colleges and then analyzed the advantages and disadvantages of traditional physical education models in colleges and universities, thus leading to the application of online college physical education technology in college physical education [10]. Finally, it is pointed out that network college physical education has solved the problem of short class hours in traditional college physical education and has broken through the limitation of time and space. The development of multimedia network technology makes it easier to achieve the goals of college physical education [11].

The researchers explained the drawbacks of traditional physical education courses, and the more difficult technical movements could not be fully demonstrated [12]. The personal quality of teachers affects the quality of physical education in colleges and universities. The process of physical education in colleges and universities cannot be personalized with students as the theme. The process of physical education in colleges and universities is restricted by weather venues and equipment. The author believes that these are the shortcomings of traditional physical education in colleges and universities. The emergence of multimedia network college physical education has just made up for these shortcomings. The multimedia display of multimedia network college physical education teaching can more vividly decompose and display the more difficult technical actions and can realize good human-computer interaction and truly achieve the theme of students [13, 14]. The personalized college physical education, the rich resources of the multimedia network, and the large amount of information can better accomplish the goals of college physical education. The author believes that the development of multimedia network college physical education in college social sports majors is an optimization of traditional college physical education teaching methods [15].

Relevant scholars discuss from the perspective of the rich network resources of multimedia network college physical education teaching [16, 17]. It describes the shortcomings of multimedia network college physical education in using network resources to improve the existing traditional college physical education teaching. The abundance of network resources can stimulate students' independent learning and interest in physical education courses [18–20]. The multimedia network college physical education teaching can be based on students. To carry out effective and reasonable personalized college physical education, in terms of technology, multimedia network college physical education can use modern multimedia technology to simulate realistic scenes and help students establish a clear representation of actions [21–23]. Finally, the author made an explanation of the rational use of network resources to improve physical education in colleges and universities.

3. 5G Multimedia Heterogeneous Multimodal Network Representation Learning Method

3.1. Distributed Architecture of the 5G Wireless Backhaul Network. In order to realize the transmission of wireless backhaul traffic in the 5G ultradense cellular network, the distributed architecture of the wireless backhaul network is usually adopted, as shown in Figure 1. A macrobase station is located in the center of a macrocell with a radius of R and controls the infinite backhaul routing of small cell base stations within the coverage of the macrocell. Within the coverage of the macrocell, $n = M + N$, small cell base stations are randomly and densely deployed. Among them, M small cell base stations connected to the core network through fiber-to-cell links are configured as backhaul gateways, whose main function is to forward backhaul traffic to the core network; the other N small cell base stations forward their backhaul traffic to M backhaul gateway. In this scenario, it is assumed that the millimeter wave transmission technology is used to transmit wireless backhaul traffic, each small cell base station has enough bandwidth for wireless backhaul transmission, and the backhaul traffic of the small cell base station is forwarded to the backhaul gateway through a multihop relay mechanism. Because the millimeter wave has strong directivity, the millimeter wave wireless backhaul network does not need to consider the interference of neighboring transmitting nodes.

Due to the characteristics of millimeter wave path loss and obvious scattering effect, it is assumed that the one-hop distance of wireless backhaul transmission does not exceed

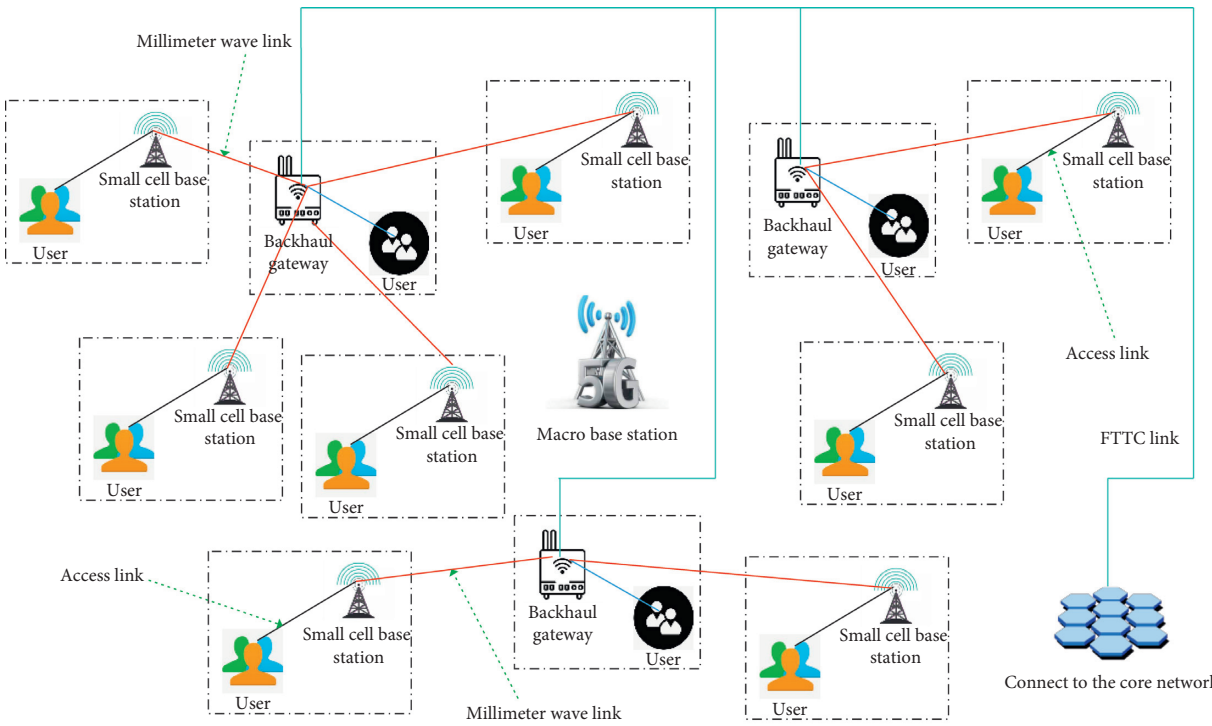

Figure 1: Distributed architecture of the 5G ultradense cellular network.

D0; that is, each small cell base station can only connect to the base station in the coverage area with the base station as the center and the radius of D0. Since the future 5G cellular network will be dense or even superdense, by setting the location of the backhaul gateway reasonably, we can think that N ordinary small cell base stations can send data to the corresponding backhaul gateway node (Figure 1).

3.2. Node Representation Learning Method Based on the Heterogeneous Network Structure. Figure 2 shows the framework of the A2CMHNE method. We propose a metapath-based method to mine the implicit structure information in heterogeneous networks and design two representation learning methods to learn the text description and image feature representation in the network, respectively, so as to make full use of the multitude in the network. Finally, the attention-based collaboration mechanism is used to integrate these three representations, so that the structural information and multimodal content information of the network can be fully utilized to alleviate the sparsity of the network and finally build a robust node representation (Figure 2).

We design a loss function based on a heterogeneous network structure, and the implicit structure information captured by the metapath can be retained as much as possible in the representation of the constraint node. Given a metapath mode mps, we can capture zero or several metapath neighbors for node v_i. We denote the set of neighboring nodes of the metapath of the node v_i in the metapath mode mps as Nmps(v_i). We model the conditional probability distribution of the neighboring nodes of the metapath:

$$p_{\text{mps}}\left(v_j \mid v_i\right) = \exp\left(c_{js}\right) \bullet \exp\left(x_{is}\right) \bullet \frac{\left(t_l + 1\right) \bullet V_{tl}}{\exp\left(c_{ks}\right) \bullet \exp\left(x_{js}\right)}. \tag{1}$$

Here, x_{is} is the representation of the node v_i, c_{js} is the representation of the context of the node v_j, t_l is the type of the tail node specified by the metapath mode mps, and V_{tl} represents the collection of nodes of the type t_l. The context of the node here refers to the neighboring node of the metapath of the node. The core idea of the formula is that if the context distribution of two nodes is similar, then the two nodes themselves tend to be similar.

3.3. Node Representation Learning Method Based on Multimodal Content. In order to utilize the multimodal content information associated with nodes in the 5G multimedia network, we learned two content representations for nodes: node representation based on text content and node representation based on visual content. In a 5G multimedia network, some nodes may be accompanied by rich text content information such as text descriptions. We use the words in these text content as nodes and together with the original nodes form a heterogeneous text network:

$$G_t = \left\{E_{\text{tc}} \;\; V_{\text{tc}}\right\}. \tag{2}$$

Similar to the idea of considering the context distribution of neighboring nodes of a metapath, we consider the distribution of text nodes associated with ordinary nodes to construct a loss function based on text content, as shown in the following formula:

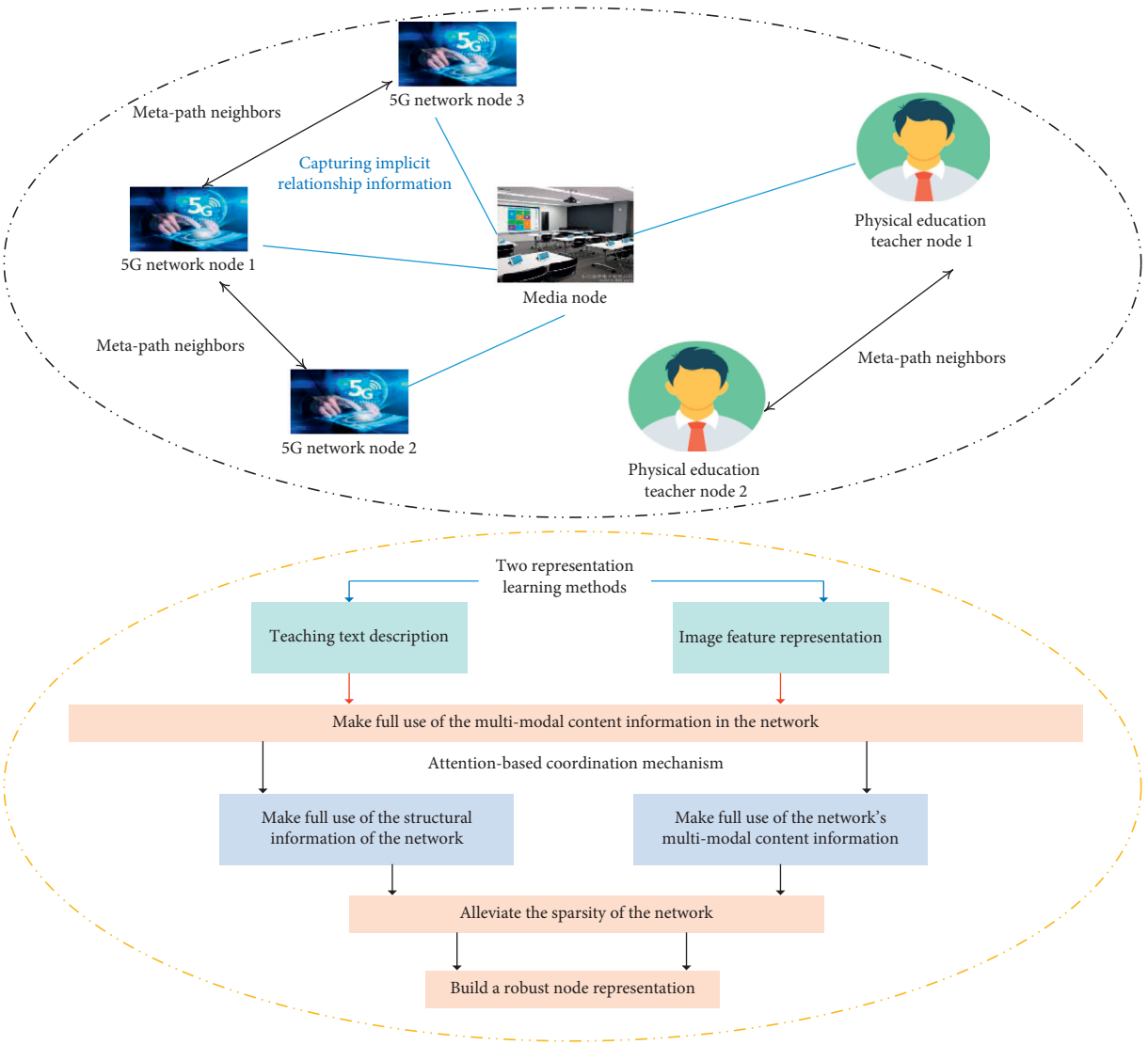

Figure 2: Overall framework diagram of node representation based on heterogeneous network structure.

$$L_{\text{text-content}} = V_{tc} \bullet \log p_{tc} v_i \bullet \log p_{tc} v_j. \tag{3}$$

The same words in different text contents correspond to the same node in the graph; otherwise, the distribution of associated text nodes will become meaningless. By optimizing the loss function $\mathscr{L}$text−content, we can learn node representation based on text content for node v_i.

When considering text content, the distribution of text nodes is meaningful because it is very common for different text contents to share text nodes (that is, contain the same words). But the visual information is very different. The visual information contained in different nodes rarely overlaps. Although in social networks and other scenarios, different articles may contain the same pictures, only considering this situation will ignore most of the visual information. If the original node and image are used to construct the network directly, most image nodes will only contain one neighbor node. Therefore, it is not feasible to construct the network directly from the original nodes and images and to learn the visual representation of the nodes based only on the structural information of the constructed network.

The content of the image itself contains rich semantic information. We can encode the image content to extract feature representations through mature technologies such as convolutional networks. Although image nodes are not shared, we can use a shared convolutional network as an encoder to extract image features to learn the representation of image nodes. We put each image as a node into the original heterogeneous network and use the deep encoder and metapath to use the content information of the image and the structure information of the heterogeneous network, respectively, and finally learn the representation of the image node. For each image node v_i, we use ResNet pretrained on ImageNet to extract its visual content features f_i.

$$L_{\text{visual-content}} = \log p_{vc} \frac{v_i}{v_j} \bullet N_{\text{mps}}. \tag{4}$$

We construct the visual content loss function based on the encoding result and the neighboring nodes of the metapath, as shown in the following formula:

$$L_{\text{visual-content}} = \log p_{vc}\left|v_i \bullet v_j\right| \bullet \left(v_j + N_{\text{mps}}\right). \quad (5)$$

In the formula, v_i is the image node, and v_j is the neighboring node of the metapath of v_i in the metapath mode. Since most image nodes have only one neighbor in the network, we use metapaths to expand their contextual information. By optimizing the image loss function $\mathscr{L}_{\text{visual-content}}$, we can get the representation of the image node. A common node may contain multiple pictures; that is, multiple image nodes will be associated. We use the average value of these image nodes as the image representation of the node.

3.4. Attention-Based Node Representation Coordination Mechanism. By optimizing the loss function $\mathscr{L}_{\text{structure}}$, $\mathscr{L}_{\text{text-content}}$, and $\mathscr{L}_{\text{visual-content}}$, we can obtain a node structure represented by x_{is} and multimodal content representation:

$$x_{ic} = \{x_{ivc} \quad x_{itc}\}. \quad (6)$$

We propose an attention-based collaboration mechanism to integrate these several representations to build a robust node representation. For each node, the structure information, text content information, and visual content information of the node have different importance to the semantics of the node. In addition, for different nodes, the distribution of the importance of this information is different. Therefore, we dynamically calculate the importance of different types of representations for each node.

Our collaboration mechanism can focus more on information that is more relevant to node semantics. Based on these different representations and corresponding weights, we can construct a robust node representation by the method shown in the following formula:

$$x_i = x_{ivc}\lambda_{ivc} - x_{itc}\lambda_{itc} - x_{is}\lambda_{is}. \quad (7)$$

For different nodes, the importance distributions of the corresponding multiple representations may be different. To this end, we introduced a self-attention mechanism to dynamically calculate the importance weight information for each node. For each node v_i, we will vertically stack its corresponding structure representation x_{is}, text content representation x_{itc}, and visual content representation x_{ivc} to form a representation matrix M_i. Based on M_i, we use the following formula to calculate the incidence matrix A_i to reflect the relationship between different representations of nodes:

$$A_i = H\left(M_i\right) \bullet G\left(M_i\right)^T. \quad (8)$$

In the formula, $G(M_i)$ and $H(M_i)$ represent two different fully connected layers, which can transform the d-dimensional eigenvector of each row in the input matrix into a new d-dimensional eigenvector and use the ReLU activation function to perform activation.

4. 5G Multimedia Network Classroom Explores the Design and Implementation of the College Sports Teaching Mode

Under the guidance of educational theory, combined with the exploration of the general process of college physical education mode and the characteristics of the multimedia network classroom environment, and in accordance with the design principles of college physical education teaching, the teaching mode in the multimedia network classroom can be constructed. It is carried out in a multimedia network classroom environment. Under the guidance of teachers, students actively explore the essence, grasp the main points of knowledge, and take the self-inquiry of students as the mainline of the exploratory college physical education teaching model.

Under the guidance of the teacher, we make full use of the functions of the multimedia network classroom environment and the organic integration of the curriculum, allowing students to observe, think, and search online to discover knowledge and design through the creative application of various tools provided by the multimedia network classroom. Figure 3 shows the design process of multimedia network classrooms exploring college physical education teaching (Figure 3).

4.1. Investigation to Determine the Target of Exploration. To carry out college physical education in a multimedia network classroom, due to the changes in the college physical education environment, teachers and students are required to have a certain level of information technology application ability to adapt to this technical classroom. Before implementing the exploration of the college physical education model in multimedia network classrooms, it is necessary to investigate the ability and level of teachers and students to apply information technology, so as to carry out corresponding training for teachers and students according to needs. In addition, it is also the primary consideration for teachers to explore the college physical education design by investigating to understand the cognitive level of students and determining the exploration goal.

The determination of the exploration goal should be based on the systematic analysis of the college physical education content, and it cannot be decided arbitrarily. Generally speaking, the key content should be explored, but not all content is suitable for inquiry, and teachers should make good choices. It also depends on what kind of inquiry abilities can be cultivated by this part of the content and the significance of these inquiry abilities to student development. Students' study preparation and study characteristics are also an important basis for determining the exploration goals. In addition, when determining the exploration goals, we must also consider making full use of the various functions of the multimedia classroom in order to achieve the best college physical education results. Teachers need to make adequate preparations before determining the exploration goals, that is, to prepare the lessons. Specific requirements are as follows.

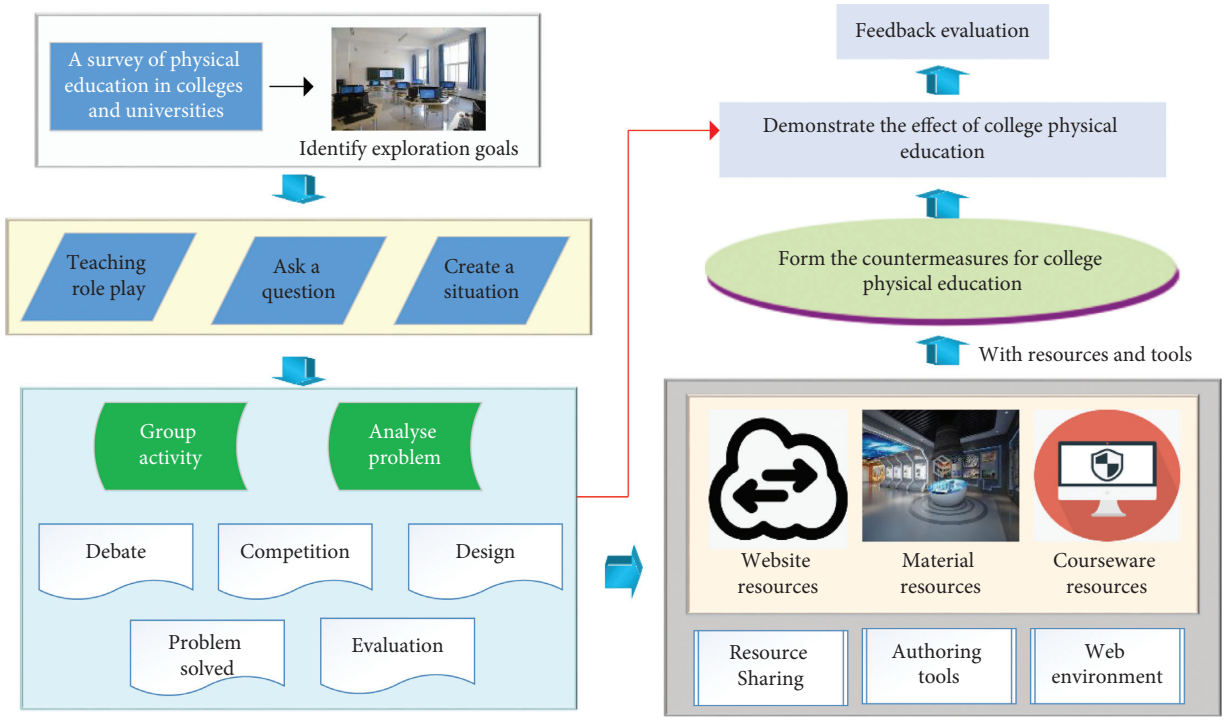

Figure 3: Inquiry into the flow chart of physical education teaching design in colleges and universities in the multimedia network classroom.

4.1.1. Preparation of Teaching Materials. Teachers should fully understand the content of the textbooks, delve into the textbooks, and understand the materials related to the content of college physical education in this course, in order to be a good tutor, help, facilitator, and academic advisor for students.

4.1.2. Preparation of Students. Teachers should understand the learning characteristics of students with different age characteristics and make corresponding investigations on the students' existing knowledge and skills, so that they can be targeted when determining the exploration goals.

4.1.3. Preparation of the Environment. Teachers should be familiar with the learning environment of the multimedia network classroom. First of all, we must understand some precautions for carrying out college physical education in multimedia network classrooms; for example, dust will generate static electricity and cause equipment failure; abnormal weather will damage equipment (too high or too high humidity, room leakage, etc.); the intensity of light will affect vision; the maintenance of computers and network equipment takes time and effort and requires professionals to maintain. Secondly, teachers should be familiar with the various functions of the multimedia network classroom in order to better carry out physical education in colleges and universities, such as group presentation, monitoring rebroadcasting, rebroadcasting, monitoring tutoring, screen recording, and other functions. Third, teachers should be familiar with commonly used computer software and be able to use this software to make electronic teaching plans with rich pictures, content-rich courseware, animations, etc.

4.2. Creating a Problem Situation to Ask Questions. The typical feature of research learning theory is that there must be context to support the problem. The context must be organized, concise, and clear, and the way the problem is presented must be novel, in order to increase the novelty of the problem and stimulate students' interest. Teachers can use multimedia network classrooms to broadcast college physical education and network cinema functions and use courseware, stories, movies, and other forms to create problem situations to present problems, so as to better arouse students' active thinking.

4.2.1. Creating a Real Situation. Constructivist learning theory emphasizes the creation of real situations and regards creating situations as a necessary prerequisite for "meaning construction" and as one of the most important contents of college physical education design. Multimedia technology happens to be the most effective tool for creating real situations. If combined with simulation technology, it can produce more immersive and realistic effects. Teachers use the network environment with multimedia technology and network technology as the core to create situations that are as realistic as possible related to the subject, so that learning can occur in situations that are basically consistent or similar to reality.

Students learning in actual situations can stimulate students' associative thinking and stimulate their interest and curiosity in learning mathematics. Learners can use

their original cognitive structure to assimilate and index the new knowledge they have learned so as to establish a connection between the new and the old knowledge and give the new knowledge a certain meaning.

4.2.2. Creating Life Scenarios. Life is the best classroom, and learning is also for a better life. Therefore, creating life situations in the classroom can not only cultivate students' practical ability but also effectively strengthen the connection between students and the reality of life, so that students can feel the existence of knowledge everywhere in life.

4.2.3. Creating Error Correction Scenarios. "Wrong is the precursor to the right." Students often make mistakes of one kind or another when solving problems. In this regard, teachers should create error correction scenarios for some obscure mistakes frequently made by students, guide students to analyze and study the causes of mistakes, find a good way to cure "mistakes," correct mistakes while knowing them, and prevent mistakes while correcting mistakes. They make up for students' shortcomings in knowledge and logical reasoning, improve the accuracy of problem-solving, and enhance the rigor of thinking. Discovery learning theory emphasizes that students' learning should be a process of active participation and discovery, rather than passively accepting knowledge. Students should be allowed to explore independently, find problems, and correct mistakes by themselves. It is necessary to create error correction situations and cultivate students' rigorous logical reasoning ability.

4.3. Analyzing and Solving Problems. According to learning needs, they analyze the subject of inquiry, formulate a subject learning plan (including determining goals, small group work, and planning progress), and organize cooperative learning groups to make full use of the functions and network environment in the multimedia network classroom. In the college physical education teaching at this stage of problem analysis, teachers should provide appropriate help and guidance, be good at selecting valuable questions or opinions among students, and guide students to discuss in order to find answers to questions. Teachers should allow students to think independently in specific operational activities, encourage students to express their opinions, and communicate with peers.

When teachers organize students' inquiry activities, they generally let students explore independently, think, and propose strategies and methods to solve problems. Because each student is a unique individual who constructs an understanding of knowledge in his own way, there must be differences between each student, and this difference is a valuable learning resource. However, the understanding of each student will also have limitations. Teachers need to organize the cooperation and exchanges between students and teachers and students on the basis of the students' personal opinions, so that different views can collide and learn from each other.

(1) Students can use the campus network and the Internet connected to the multimedia network classroom to collect materials, develop ideas, and conduct active and independent exploration of problems according to their needs. (2) The multimedia classroom group discussion, electronic forum, and other functions can be used to communicate and cooperate, so that students can analyze problems more abundantly and comprehensively and learn to cooperate with each other in the process. (3) Students browse related webpages and resources through browsers in a network environment, think about and analyze the information they have obtained, remove the false and keep the truth, and choose the best and eliminate the inferior. (4) They freely organize study groups according to their needs and carry out relevant collaborative learning activities (such as competition, debate, design, problem-solving, or role-playing). (5) With the help of network tools such as NetMeeting, Internet Phone, ICQ, e-mail, Chat Room, BBS, and Blog, we can communicate with each other and participate in various types of dialogue, negotiation, and discussion activities.

According to the results of the analysis, students will be instructed to remove the false and preserve the truth, choose the best and remove the inferior, discuss with each other, draw the conclusion of the problem, and create a research report or electronic work related to the theme. The way to solve the problem and the innovation of the conclusion requires the educational wisdom of teachers and the imagination and creativity of students. The educational wisdom of teachers is to be good at organizing and managing the classroom. The cultivation and improvement of students' imagination and creativity require an open and relaxed environment.

The college physical education function of the multimedia network classroom not only provides teachers with a way to manage the classroom but also provides an environment where students can practice freely. The multimedia network classroom provides each student with a networked computer that can be operated independently, which can give full play to the specialties of individualization and interactivity. Students can independently participate in learning activities and can adjust the learning progress by themselves; teachers are in a network environment. Physical education in colleges and universities can use the broadcast function of the network to complete class collective teaching. It can realize cooperative learning between groups through online functions and communicate with students through monitoring/monitoring and control functions, making college physical education not only suitable for most students. At the same time, it also creates individual learning and development conditions for students of different levels. Therefore, it can be more conducive to the development of students' independent learning and exploratory learning.

(1) Students can use the group discussion, electronic forum, and other functions of the multimedia classroom to realize communication. (2) Students can express their conclusions in written form or verbally. (3) Students can use word processing software, spreadsheet software, and animation design software and can also use "geometric

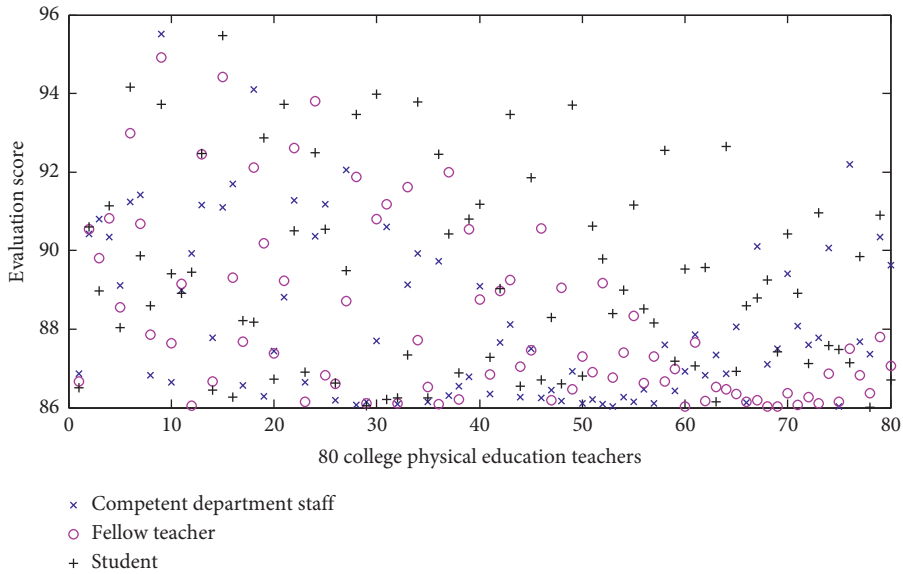

Figure 4: Evaluation subject scores based on 5G multimedia network teaching.

sketchpad," "drawing," "composition" tools, electronic manuscript production or web development, and other information "integration" tools to create works. (4) It can be sent to teachers and other students through network sharing, e-mail, or using the submission function of the multimedia network classroom.

5. Research Results and Analysis

5.1. Analysis of Teaching Evaluation of Physical Education Teachers under 5G Multimedia Network Technology

5.1.1. Scoring Situation of the Evaluation Subject. The evaluation subject score based on 5G multimedia network teaching is shown in Figure 4. The main body of evaluation is the evaluation of students and the evaluation of personnel in the competent department. The evaluation mode is mainly the evaluation of the superior to the inferior and the evaluation of the students. Therefore, the teaching evaluation of physical education teachers does not solicit the personal opinions of physical education teachers and also ignores the evaluation of peer physical education teachers. Although students participate in the evaluation of physical education teachers, in fact, most physical education teachers do not pay much attention to students' feedback on the results of their college physical education evaluation results. This is due to the implementation of a centralized and unified administrative management system in education in my country (Figure 4).

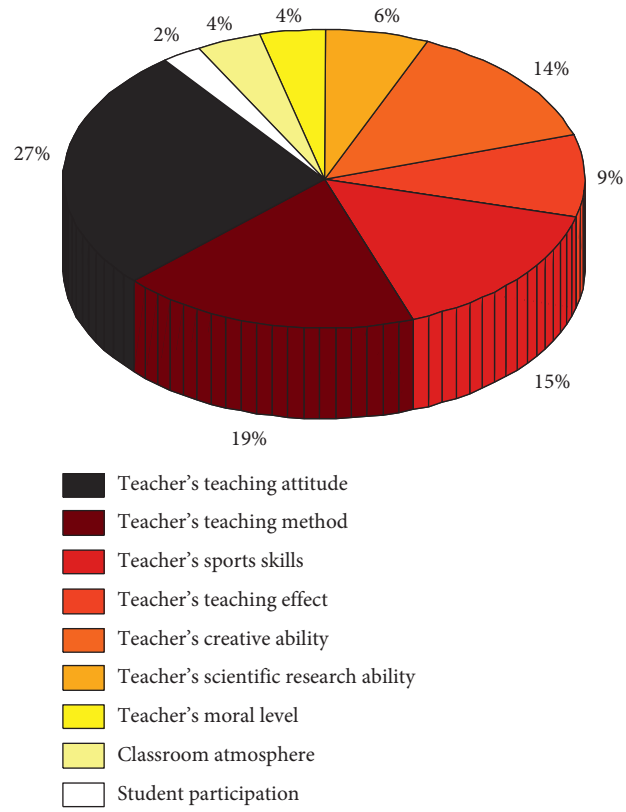

Figure 5: Evaluation proportion.

5.1.2. Proportion of Evaluation Content. From Figure 5, the content of the teaching evaluation of physical education teachers is mainly based on the teachers' college physical education teaching attitude, college physical education teaching methods, athletic ability, moral quality, and college physical education teaching effects. In addition, it also includes the innovation ability of physical education teachers, the scientific research ability of college physical education, the degree of student participation in the classroom, and the classroom atmosphere. Therefore, most physical education teachers focus on the meticulous design of college physical education and the application of college physical education skills and attach importance to the external work performance of teachers (Figure 5).

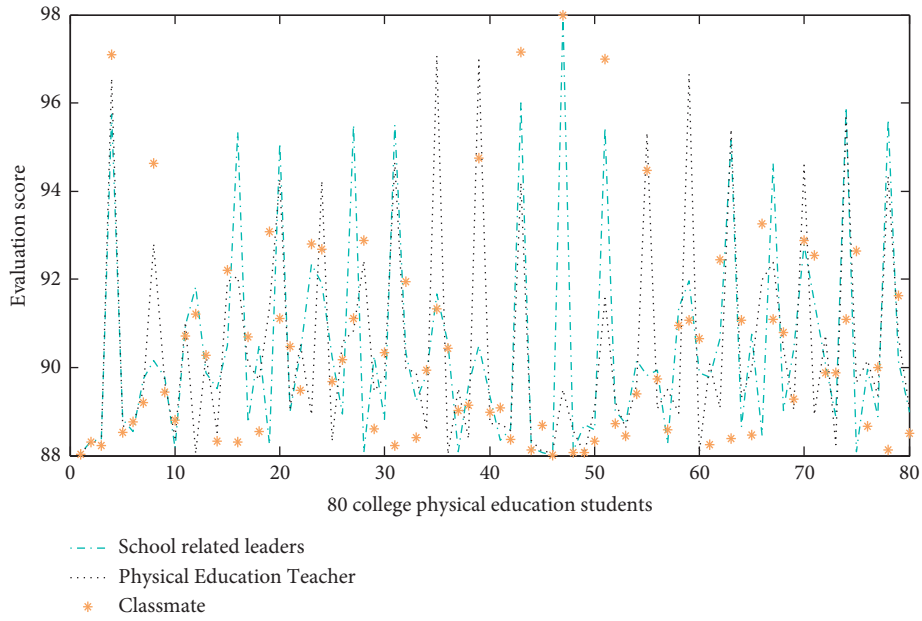

Figure 6: Evaluation subject scores based on 5G multimedia network teaching.

5.2. Analysis of Student Evaluation of College Physical Education Teaching under 5G Multimedia Network Technology

5.2.1. Evaluation Subject's Scoring Situation. Figure 6 shows the evaluation subject scores based on 5G multimedia network teaching. The main body of the evaluation is physical education teachers, and the evaluation mode is mainly top-down evaluation, ignoring the possibility of student self-evaluation. Therefore, the evaluation of students' college physical education ignores the students' self-evaluation (Figure 6).

5.2.2. Proportion of the Evaluation Content. From Figure 7, the content of the evaluation of physical education teaching in colleges and universities for students is mainly based on theoretical knowledge of physical education, sports skills, classroom performance, and physical fitness. In addition, it also includes the evaluation of students' innovation ability, sports interest, and mental health level. Therefore, in addition to paying attention to some common content in the evaluation content, the differences of individual students should not be ignored (Figure 7).

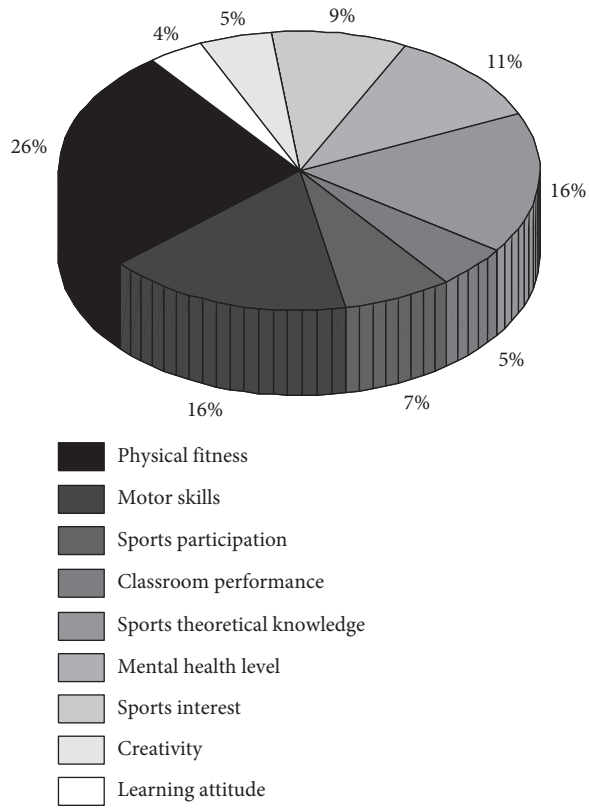

Figure 7: Proportion of evaluation content.

5.3. Survey Results and Analysis of Physical Education Teachers' Teaching Evaluation Indicators under 5G Multimedia Network Technology. From Figure 8, the average of the three first-level indicators is above 89, which is basically recognized by experts. Some experts suggested that the preparation of physical education in colleges and universities should take into account the physical teaching etiquette in colleges, teachers and students greet each other, and the habit of conscious exercise should be increased in the index of college physical education teaching effect, and students' interest in sports should be increased. Moreover, the Kendall harmony coefficient in the first round is 0.061, $P > 0.05$, so the coordination degree of the expert index evaluation results is very low and inconsistent (Figure 8).

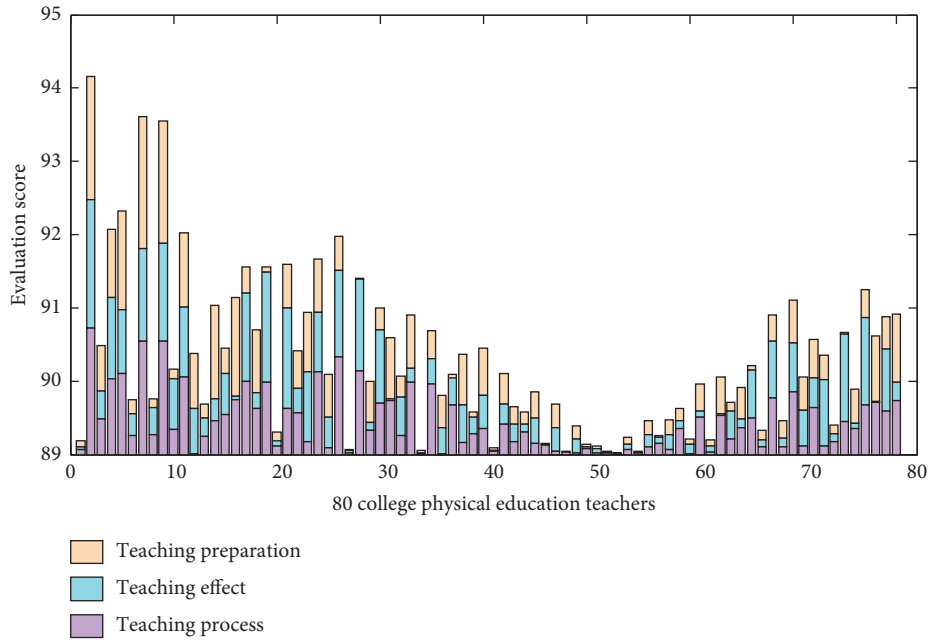

Figure 8: Scores of the first round of first-level indicators under 5G multimedia network technology.

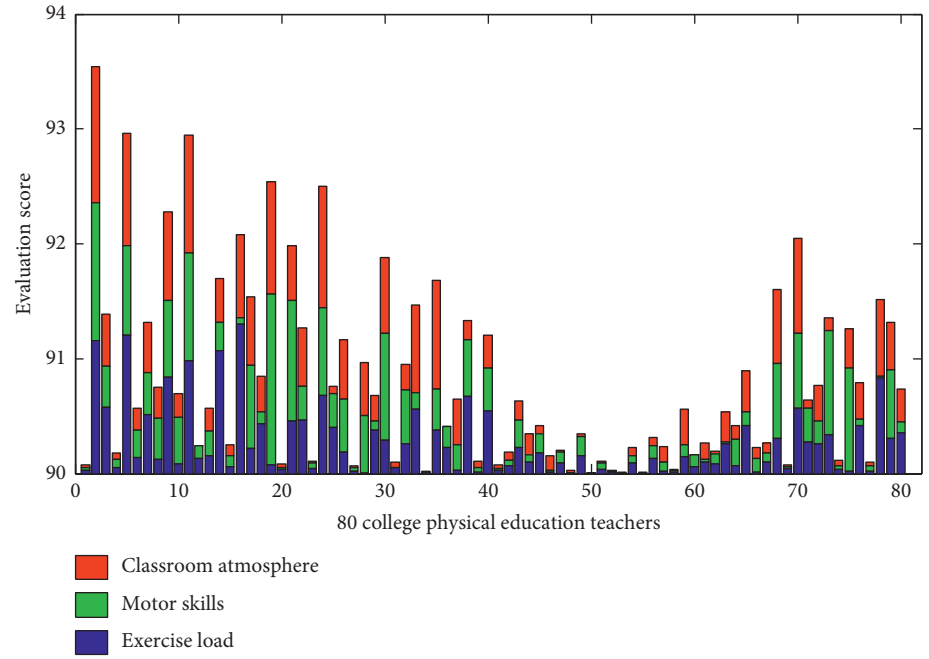

Figure 9: The first round of secondary index scores under 5G multimedia network technology.

As shown in Figure 9, the averages of the three secondary indicators in the first round are all greater than 90, indicating that the initially designed secondary indicators have basically been recognized by experts. Some experts pointed out that the index of physical fitness includes the index of physical fitness, and these two should not exist side by side. The basic knowledge of sports theory also needs to be considered. The Kendall harmony coefficient is 0.087, $P < 0.05$, indicating that the expert evaluation results are consistent but not highly coordinated (Figure 9).

5.4. Survey Results and Analysis of Evaluation Indicators for College Physical Education Students under 5G Multimedia Network Technology. From Figure 10, the averages of the three first-level indicators are all above 91, so they are basically recognized by experts. Among them, the average of the learning process is the highest, and the coefficient of variation is also the smallest, indicating the highest degree of recognition by experts; the coefficient of variation of learning preparation and learning effect is larger. Several experts have put forward suggestions on these two

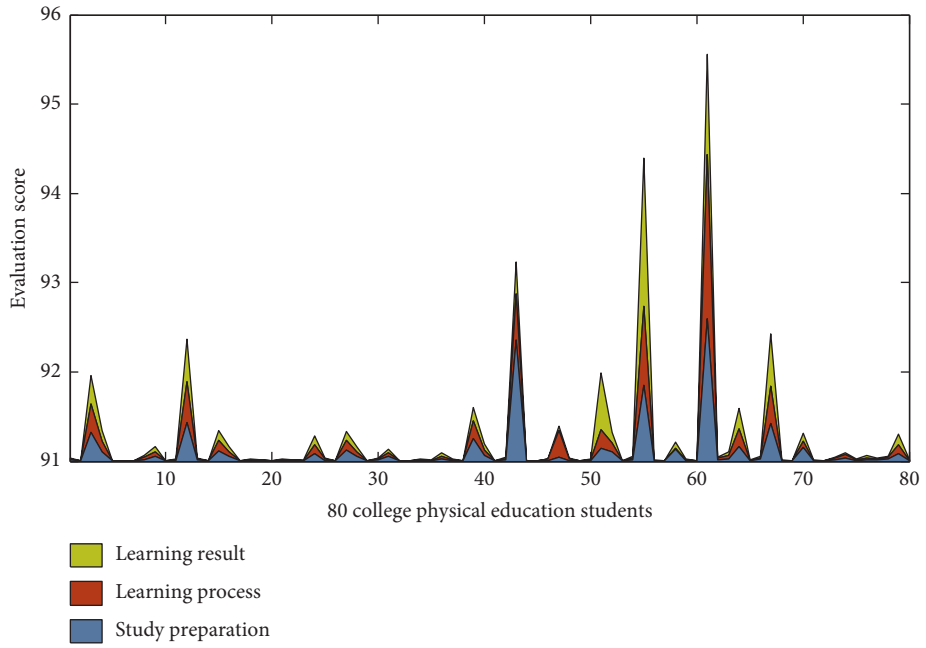

Figure 10: The first round of the first-level index score.

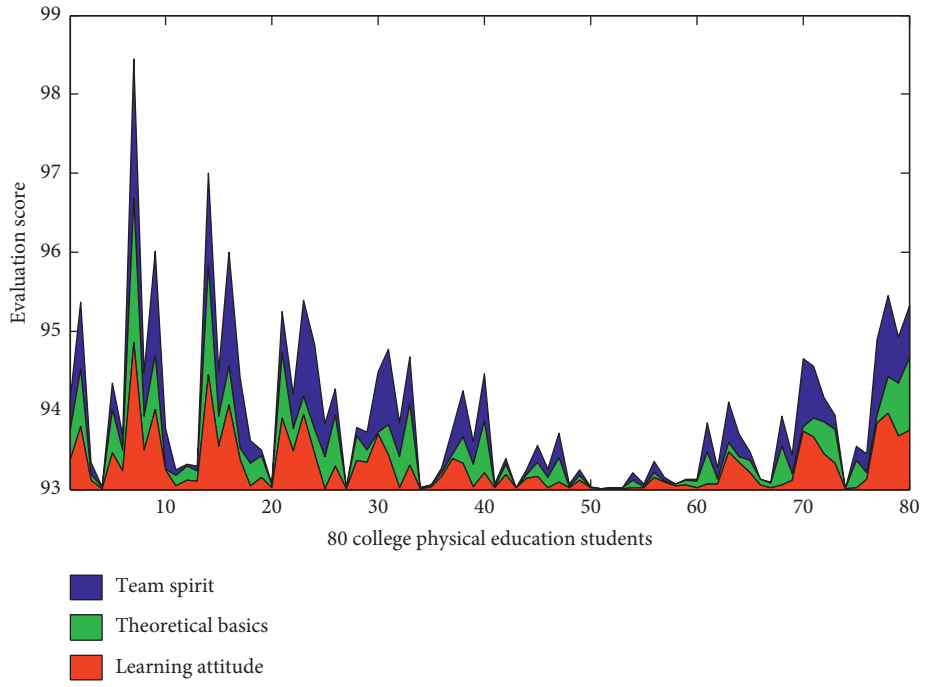

Figure 11: Scores of the first round of secondary indicators.

indicators: college physical education teaching etiquette should be considered in the study preparation, hello to teachers, and learning effect indicators should increase the habit formation of students' conscious exercise and the degree of interest in sports. The Kendall harmony coefficient is 0.01, $P > 0.05$. Therefore, the coordination degree of the expert evaluation results is very low and inconsistent, and the indicators need to be further modified. Figure 11 shows that the average of the three secondary indicators in the first round of the survey is greater than 93, indicating that the primary design of the secondary indicators has basically been recognized by experts (Figures 10 and 11).

6. Conclusion

In order to solve the heterogeneity of the network, the model uses metapaths to capture the hidden structural information in the heterogeneous multimodal network and learns the

node representation based on the network structure. In order to solve the sparsity of the network, the model uses an attention-based collaboration mechanism to integrate the structural representation of the node and the multimodal content representation, allowing them to complement each other to build a robust node representation. In the integration process, the attention mechanism is responsible for dynamically calculating the weights represented by different types of nodes for each node. The implementation of inquiry into college physical education in multimedia network classrooms can effectively influence and increase students' interest in learning, improve students' learning and practical ability, and provide necessary conditions for students to explore scientific knowledge courageously. Exploring the college physical education teaching model in the multimedia network classroom meets the requirements of the new curriculum that emphasizes students' independent exploration, cultivates students' innovative spirit and practical ability, and provides a way for the majority of educators to conduct college physical education in the multimedia network classroom environment. Under the background of the 5G multimedia network application, the main body of college physical education evaluation includes physical education teachers, students, peers, and personnel of college physical education departments. A combination of "self-evaluation-student evaluation-peer review-evaluation by the competent department personnel" is adopted for physical education teachers, and a combination of "self-evaluation-group evaluation-teacher evaluation" is adopted for students; the evaluation index system is evaluated by physical education teachers. The index system and the evaluation index system of physical education teaching in colleges and universities are constituted. The evaluation of physical education teaching in colleges and universities lacks individuation and flexibility. Different evaluation systems should be constructed according to the professional differences of schools and colleges. For physical education teachers, the principle of differential treatment should also be adopted for college physical education. The evaluation process should be comprehensive, the evaluation process and evaluation results should be reflected, and the role of feedback should be emphasized. This article explores the construction of the evaluation system of physical education in colleges and universities, which can be used as a reference for the reform of the evaluation system of college physical education. However, due to technical limitations and feasibility, the selection of college physical education evaluation indicators is not comprehensive enough for the 5G multimedia network era, so its conclusions may have certain limitations and deficiencies.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare no conflicts of interest.

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