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Research on the Integration and Efficiency Enhancement of Research Resources in the Private University's International Business Discipline from a Distributed Computing Perspective: A Case Study of Xiamen Institute of Technology

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ABSTRACT
Aiming at the many problems in research resource management in private universities, this paper takes the integration of research resources in international business discipline of Xiamen Institute of Technology as an example, proposes a global integration and dynamic allocation model of research resources in distributed computing environment based on mobile agent (DCMA), and designs a dynamic bidirectional matching method of tasks and resources (DBMM) in order to improve the effectiveness of distributed computing. Experiments show that the proposed DBMM algorithm outperforms the LDCP algorithm and the hierarchical node sorting algorithm (SNLDD) in three metrics, namely, scheduling length, acceleration ratio and computational efficiency. Compared with LDCP and SNLDD, the scheduling length of DBMM algorithm is shortened by an average of 19.89% and 11.81%, the acceleration ratio is improved by an average of 19.77% and 9.26%, and the computational efficiency is increased by an average of 10.74% and 3.72%, which further improves the resource utilization rate of distributed computing system. Experiments were conducted using the research resource integration model, which achieved better efficacy in terms of probability value, goodness-of-fit, and stability of research resource integration in international business disciplines compared with the gray correlation analysis method. This paper provides an example reference for distributed computing system to realize research resource integration and efficiency improvement.

Keywords: distributed computing, research resource integration, mobile agent, two-way matching

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1. Introduction

With the deepening of reform and opening up, the rapid development of China's society and economy has led to an increasing demand for higher education personnel. Coupled with the lack of national investment in education, the demand for private colleges and universities has further increased. Therefore, more and more private capital has been invested in the field of higher education, founded a large number of private colleges and universities [1-4]. The discipline of international business is the study of multinational enterprises in the international market for business activities, is China's private colleges and universities focus on the development of the discipline, which is mainly the study of international trade, international markets, international investment and international finance and other areas of knowledge and theory [5-8]. The research object of this discipline is multinational corporations, and the research content involves the development of international markets, the operation of international trade, international investment decision-making, etc. And with the acceleration of globalization, the discipline of international business has received more and more attention and importance [9-12].

The integration of research resources in international business discipline means that scientific researchers in the discipline enhance the efficiency and quality of research by integrating various resources, including literature databases, experimental equipment, talents and so on. It can help researchers avoid duplication of labor, reduce the waste of resources, and improve the output efficiency of research results [13-16]. However, research resource integration also faces some challenges, such as data security, academic cooperation and resource cost, etc. Through reasonable solutions, these challenges can be overcome and the maximization of research resources can be achieved. Only by continuously improving the methods and mechanisms of scientific research resource integration can we better promote the progress and development of scientific research [17-20].

This paper firstly explores the realization path of private university research resource integration based on distributed computing, on the basis of which a global integration and dynamic allocation model of research resources based on mobile Agent is constructed. At the same time, a dynamic bidirectional matching method (DBMM) for tasks and resources is designed to enhance the effectiveness of distributed computing system by modeling the characteristics of tasks and resources and calculating their bi-directional integrated matching degree. Then, in order to verify the effectiveness of the proposed DBMM algorithm, it is compared with the LDCP and SNLDD algorithms in the dimensions of scheduling length, acceleration ratio and computational efficiency. Finally, Xiamen Institute of Technology is taken as an example to analyze the superiority of this paper's research resource integration method in the task of research resource integration in the discipline of international business.

2. Integration of private university research resources based on distributed computing

2.1. Distributed computing

Distributed computing is a computing model in which a computing task is decomposed into multiple subtasks, and in parallel on multiple computers or nodes, these subtasks are executed, and the results of the computation are integrated to obtain the final result. Distributed computing has the following characteristics:

1) Since the computing resources in a distributed computing system are distributed over multiple nodes, the system has high reliability. Even if a node fails, other nodes can still continue to work without affecting the operation of the whole system.

2) Distributed computing system can fully utilize the parallel computing capability of multiple computing nodes to achieve high-performance computing. Through the parallel execution of tasks, the system can complete large-scale computing tasks in a shorter period of time, improving computing efficiency.
3) The distributed computing system has good scalability, and can dynamically increase or decrease the number of computing nodes according to the demand to meet the growing demand for computing. This scalability allows the system to flexibly adapt to computing tasks of different sizes and complexities.
4) The distributed computing environment has a high degree of flexibility and can be customized and configured according to specific application scenarios and needs. Users select appropriate computing resources and algorithms according to their needs and adjust the parameters and configuration of the system to achieve more flexible and efficient computing.

2.2. Integration of scientific research resources based on a distributed information sharing platform

This paper takes Xiamen Institute of Technology as an example to explore the integration of research resources and effectiveness enhancement of international business disciplines in private colleges and universities. It is found that Xiamen Institute of Technology, as a private university, has problems such as resource dispersion, insufficient computing capacity and data silos in the integration of research resources in international business disciplines. For this reason, this paper introduces a distributed computing system and realizes the effective integration of scientific research resources in international business disciplines by constructing a distributed information sharing platform.

Distributed information sharing platform is an effective way to realize the Pareto improvement of research resources integration. Information sharing can be realized by constructing a distributed network information platform covering all elements in the field of scientific research resources, and its specific realization arrangement is described below.

2.2.1. Realization of scientific research resource information release. The realization of scientific research resource information release is a prerequisite for realizing the effective integration of scientific research resources in private universities. First of all, in view of the security and operability of the platform operation, the membership system and audit system should be implemented. If the researchers want to enjoy the services of the information platform, they should fill in the real information according to the relevant requirements and register as members of the information system platform, so as to facilitate the audit of the information of the researchers and the contact between the researchers. After registering as a member, researchers can choose the corresponding interface, or resource supply platform or resource demand platform to release the information they need according to their own needs.

2.2.2. Realization of matching transactions of scientific research resources. The realization of matching transaction of scientific research resources is the key to realize the effective integration of scientific research resources in private universities. When the amount of resource information on the system platform is gathered to a certain scale and the supply and demand are basically equal, the platform can be utilized to match and trade the corresponding resources. Researchers can first search for the information they want through the search engine of the information system platform, directly in the research resource database. If there is suitable information, they can contact them for price negotiation, on-site verification, signing of contract, physical delivery and so on. If there is no suitable transaction at this stage, you can post the information you need on the corresponding interface according to the above requirements, so as to facilitate other people's search and matching.

2.2.3. Statistics on indicators related to scientific research resource integration platforms. The statistics of the relevant indicators of the research resources integration platform is a reflection of the realization of the effective integration of research resources in private universities. As the manager or operator of the scientific research resources integration platform, the statistical analysis of the indicators reflected in the system platform, such as the number of visits, member registration, resource concern rate, etc., can better understand the current operation of the system platform and make corresponding modifications in a timely manner, such as based on the statistics of the number of visits to the website, the popularity of the information system platform can be quantitatively reflected in the rate of concern, and if it is found that visits are gradually decreasing, it means that the popularity and concern rate of the system is declining, and measures should be taken, such as increasing the publicity of the system. If it is found that the number of visits is gradually decreasing, it means that the popularity and attention rate of the system are tending to decline, and thus measures should be taken, such as increasing the publicity of the system and improving the service functions of the system to attract more researchers.

2.2.4. Arrangements for corresponding safeguards. The good operation of the front stage cannot be separated from the perfect guarantee of the backstage. While constructing or operating the information system platform for integrating scientific research resources of international business disciplines in private colleges and universities, corresponding guarantee measures are also needed.

1) Talents, to break the shackles and restrictions of the household registration system and social security system, the comprehensive use of a variety of incentives (such as knowledge incentives, cultural incentives, trust incentives, etc.) to encourage the flow of talent and interchange.

2) In terms of funding, it is necessary to optimize the funding structure, increase the investment in basic fields, and effectively improve the development potential and follow-up power of scientific research.

3) In terms of the source of scientific research funding, we should encourage and support the participation of socialized funds in the process of integrating scientific research resources, so as to supplement and enhance the vitality and strength of scientific research resources integration through the intervention of socialized funds.

4) In terms of equipment, it is necessary to eliminate image projects, the concept of “seeking for completeness” and “fear of the future” thinking, and strengthen the utilization of scientific research equipment based on the concept of sharing and common prosperity.

5) Project, real-time tracking project declaration or projects under construction, encourage the majority of researchers to share the projects they have applied or are applying for, and at the same time to increase the transparency of project approval and project cooperation, improve the enthusiasm of researchers.

6) In terms of achievements, we should encourage the majority of scientific researchers to strengthen exchanges between the industry, academia and research institutes on the basis of protecting intellectual property rights, accelerating the industrialization and commercialization process, and improving the utilization rate of achievements.

On the basis of the above scientific research resource sharing, it should also strengthen the investment and support of network technology construction of the system platform, and guarantee the structure and realization of the system platform with solid financial backing and technological support, and should strengthen the network security technology, and prevent the damage and attack of malicious behaviors with solid security prevention technology. Finally, there should be corresponding laws and regulations on the management of scientific research resource sharing to ensure the order, legality and efficiency of scientific research resource integration.

3. Model for integrating and allocating research resources based on distributed computing

This paper constructs a global integration model of resources based on mobile Agent and proposes a dynamic bidirectional matching method of tasks and resources, so as to realize the global integration and efficient allocation of research resources of international business disciplines in private universities based on distributed computing.

3.1. Global Integration and Allocation of Research Resources Based on Mobile Agents

3.1.1. Structure of the model of global integration and allocation of scientific research resources. The model structure of integrating and allocating research resources of international business discipline in private universities based on multi-agent (intelligent Agent and mobile Agent) distributed computing [21] environment is shown in Fig. 1, which mainly consists of three parts: distributed cluster research resource service agent e-DRSB, service provider cluster and researchers.

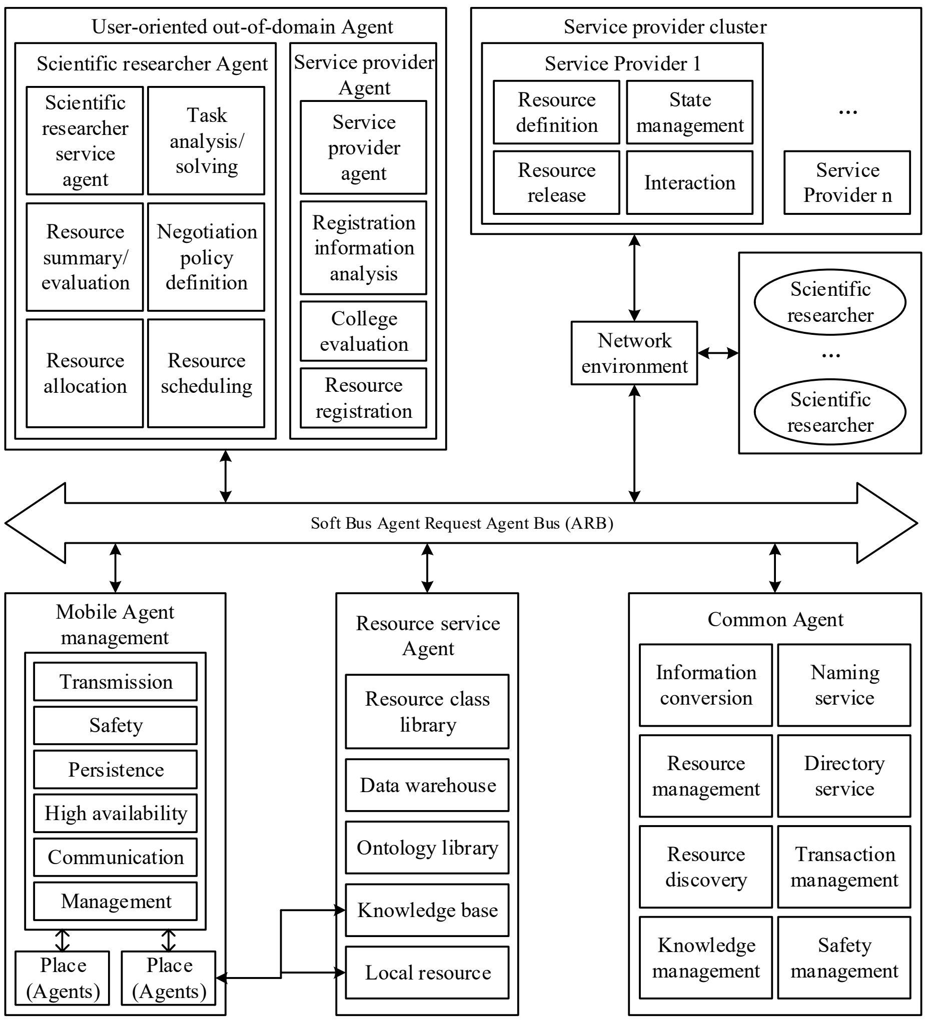


Fig. 1. Model structure of scientific research resource integration and allocation

1) e-DRSB. e-DRSB is constructed by Xiamen Institute of Technology or a third-party university to realize global integration and dynamic allocation of distributed university research resources. The service provider is responsible for providing various physical resources and registering the resource index information in e-DRSB. Researchers can apply for resources to e-DRSB, which is either a member of the cluster or a general demand customer. Mobile Agent can help e-DRSB, service providers and

researchers to realize the network interaction, improve the intelligence of the system, reduce the network traffic and shield the specific details of the interaction.

The e-DRSB is the core of the whole system, including user-oriented Domain Agent, Mobile Agent management artifacts, Public Agent, CARBA/ARB bus and Resource Service Agent.

2) Service Provider. Service providers can establish mobile Agent platform based on ARB bus according to the needs, for large universities to establish complete mobile Agent platform, and for small universities to download the core components of mobile Agent platform. They provide and distribute usable resources to the network, and define, distribute, monitor and manage their resources in a standardized way, and at the same time interact locally with Mobile Agents from the field.

3) Mobile Agent Model in Distributed Computing Environment. In a distributed computing environment, a mobile Agent (denoted as DCMA) encapsulates the information and requirements of the resources needed by the user, migrates to the host where the service provider is located, and interacts with it locally to obtain the required resource information. Here, DCMA is modeled uniformly and a canonical model BPG for mobile agent is proposed.The structure of BPG model for DCMA is shown in Fig. 2.

Among them, the perception component senses the external environment and makes certain abstraction of related information. The information parsing sub-component extracts important information and stimuli from the external environment and transforms them into a form that can be processed by the system and submits them to the information conversion sub-component. The conversion sub-component models the information and stores it to form the Belief of the DCMA.Each DCMA plans its behavior based on the set of goals, travel plan, its own state and experience, establishes a sequence of recent actions, and informs the decision management component. The Decision/Management component is responsible for the coordination of the components, and its inputs are the action plan generated by the Planning component, the notification from the Perception component, and so on. The execution component responds to the outside world by making appropriate actions based on the action commands from the transmitter.

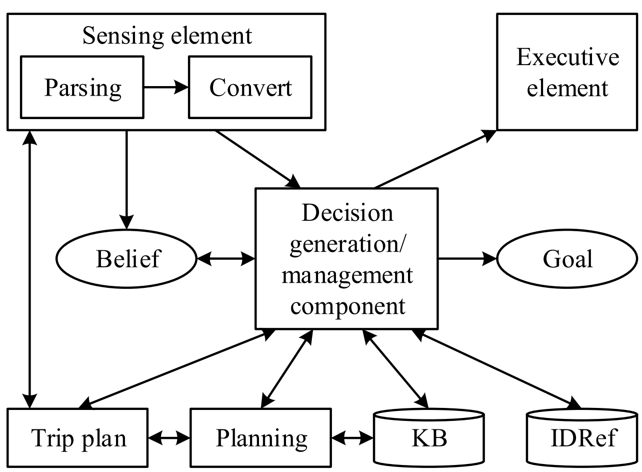


Fig. 2. BPG model structure of DCMA

4) Behavioral Interaction Process Based on Mobile Agent. In the interaction process with the service provider, the Mobile Agent makes a resource request and detects the attributes of the resource one by one according to its encapsulated resource attributes and requirements. The behavioral states and changes of the Mobile Agent are shown in Figure 3.

When the Mobile Agent migrates to the service provider, it makes a resource request and enters the running state. The mobile Agent in the running state enters the waiting state as it waits for information from the service provider. When the waiting time Tw is too long, an exception is thrown. The mobile Agent in the running process may also have an exception for various reasons. When the exception is resolved, it is re-run, otherwise the task is canceled. When the execution is smooth, then the task is completed, i.e., it is determined whether the service provider's research resources meet the requirements.

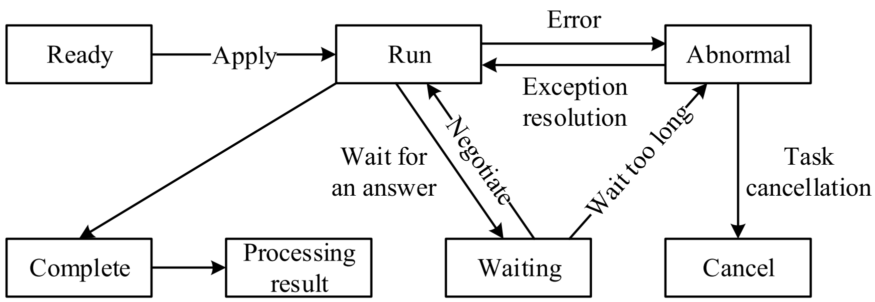


Fig. 3. Behavior state change in the interactive process

3.1.2. Global integration of distributed university research resources. Under the distributed computing environment, each service provider encapsulates the scientific research service resources provided by mobile agents and submits them to e-DRSB to realize the registration of shared resources. Based on the ontology, e-DRSB analyzes the information of these scientific research resources such as type and functional attributes, extracts the key information of scientific research resources and stores it. When there are resources to be registered and modified, e-DRSB is responsible for registering and updating the resource information at the appropriate location.

1) Shared research resource class information model. The university research resources in the distributed computing environment have a wide variety, huge quantity, and huge difference in performance and characteristics. Therefore, only the organized and abstracted research resource class information is stored in the shared research resource library of e-DRSB. The shared research resource class information model is represented by a 4-tuple:

$$\text{ResClass}=\{\text{RCName,RCSt,RCPrS,RInfList}\} \tag{1}$$

$$\text{RCPrS}=\{\text{RCAbiS,RCKeyAtriS}\} \tag{2}$$

$$\text{ResInf}=\{\text{Name,Enterp,Address,URL,State}\} \tag{3}$$

Where, RCName denotes the name of the research resource class, which uniquely identifies the research resource class, RCSt describes the frequency of use of the resource f_R. RCPrS describes the attributes, characteristics, etc. of the research resource class, including the capability attribute of the research resource, RCAbiS, and the key attribute, RCKeyAtriS. RInfList describes the specific resources and their key information contained in the research resource class. RInfList describes the specific resources contained in the research resource class and their key information descriptions, Name indicates the name of the research resource, Enterp indicates the research resource provider, Address indicates the address where the university is located, URL indicates the specific network address of the research resource, and State indicates the status of the research resource, with 0 being busy and 1 being idle.

2) Access and access mechanism of shared resources. Access frequency f_R defines the number of times a certain type of research resource (denoted as resource class) is used Cs within a certain period of time ΔT. i.e:

$$f_R = \frac{Cs}{\Delta T} = \frac{\text{Number of visits}}{\text{Current time} - \text{Last detection time}} \tag{4}$$

All the research resources (ResA) are divided into priority access resources (ResP) and general access resources (ResU) and placed in the priority access resource indexing library and general access resource indexing library, respectively. Among them, the priority access resources are the f_R higher resources, which are prioritized to be retrieved when they are used. General access resources are the resources with f_R lower. Therefore, there are:

$$ResP \cup ResU = ResA; ResP \cap ResU = \Phi \tag{5}$$

Meanwhile, based on the type and ontology of research resources, the shared resources are classified into Priority Access Resource Class RPC_i and General Access Resource Class RUC_i. Each RPC_i or RUC_i contains multiple Research Resource Entities PR or UR, viz:

$$RPC_i = \{PR_{i1}, PR_{i2}, \ldots, PR_{ih}\} \tag{6}$$

$$RUC_i = \{UR_{i1}, UR_{i2}, \ldots, UR_{iq}\} \tag{7}$$

where h, q is the number of research resource entities.

Therefore, there are:

$$RPC_i \cap RUC_j = \Phi \tag{8}$$

$$RPC_i \cap RPC_j = \Phi \tag{9}$$

$$RUC_i \cap RUC_j = \Phi \tag{10}$$

$$\{PR_{i1}, PR_{i2}, \ldots, PR_{ih}\} \cap \{UR_{j1}, UR_{j2}, \ldots, UR_{ja}\} = \Phi \tag{11}$$

$$\{PR_{i1}, PR_{i2}, \ldots, PR_{im}\} \cap \{PR_{u1}, PR_{u2}, \ldots, PR_{un}\} = \Phi \tag{12}$$

$$\{UR_{i1}, UR_{i2}, \ldots, UR_{ig}\} \cap \{UR_{j1}, UR_{j2} \ldots UR_{jz}\} = \Phi \tag{13}$$

That is, resource class RPC_i is unique in the definition of a research resource. The same resource entity PR_{ij} belongs to only one resource class.

When a shared resource is accessed, the system determines the research resource class to which the resource belongs based on the ontology. Then access according to the following rules:

(1) Find the prioritized access repository for matching resource class RPC_i. If the matching resource class is successfully found, a Mobile Agent is dispatched to interact with the service provider based on the resource $PR_{i1}, PR_{i2}, \ldots, PR_{ik}$ location. The access frequency of resource class RPC_i is +1.

(2) In addition, follow the same steps to find the matching resource class RUC_j in the general resource repository.

3) Displacement strategy for shared research resource classes. For shared research resources, their status is dynamically changing due to the frequency f_R of access, i.e., f_R is higher in a certain time period ΔT_i and when it comes to the next period ΔT_{i+1}, f_R will be low. Consequently, this results in the scientific research resources moving between the prioritized and general resource pools.

For this reason, a threshold value for the frequency of use of objects in the research resource class $f_{\min}$ is defined, $f_{\min}$ determined according to actual needs, and a hit rate of 70% is generally guaranteed for finding research resource entities in the prioritized access repository. Detect and calculate the scientific research resources in the prioritized resource indexing library and the general resource indexing library respectively at regular intervals ΔT. If the current research resource class ResC is used $f_{ResC} \geq f_{\min}$ frequently, the resource class R_{ResC} and the specific resources it contains are placed in the priority resource indexing library, otherwise, they are placed in the general resource indexing library.

3.2. Methodology for dynamic two-way matching of tasks and resources

In this paper, we propose a Dynamic Bidirectional Matching Method (DBMM) for tasks and resources for wide-area distributed computing environments [22]. The DBMM process is shown in Fig. 4. The method generates modeled descriptions of task requirements and resource capabilities by analyzing diverse task requirements and resource capabilities characteristics to simplify the matching process between tasks and resources. On this basis, the task-oriented matching degree and resource-oriented matching degree are defined to portray the preferences of task perspective and resource perspective, and the two-way comprehensive matching degree of task and resource is defined based on their two-way consistency and two-way complementarity, so as to quantify the degree of fitness between task requirements and resource capabilities, and realize the efficient matching of diversified task requirements and resource capabilities in wide-area environments.

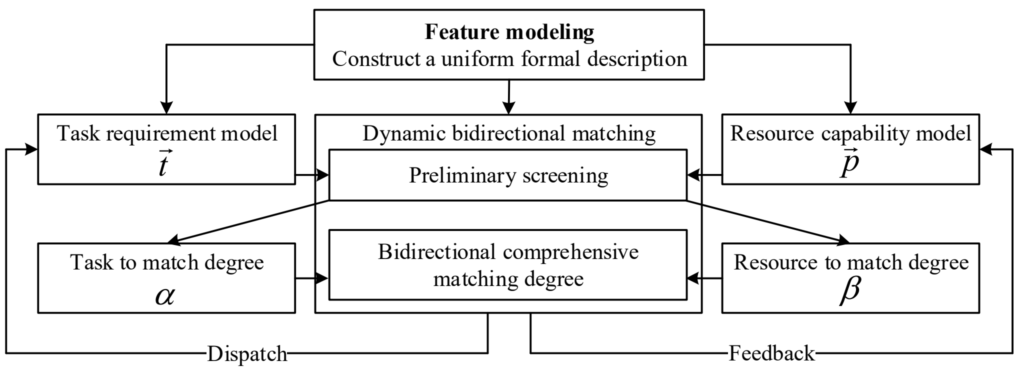


Fig. 4. DBMM process

3.2.1. Task and resource characterization modeling. For the convenience of description, this paper sets the tasks and resources as follows:

1) Use task matrix $T = [t_1, t_2, t_3, \cdots, t_M]^T$ to describe all existing tasks in the computing platform, and set that there are M computing tasks in total, and these tasks cannot be cut again in the subsequent scheduling and execution process.

2) Resource matrix $P = [p_1, p_2, p_3, \cdots, p_N]^T$ describes all the computing centers in the computing platform, and it is set that there are N computing centers, which are geographically dispersed but interconnected in the network, and these computing centers contain multiple computing resources such as computation, storage, application, network, and so on, and thus each computing center can be regarded as a "resource aggregate" containing multiple computing resources. Therefore, each arithmetic center can be regarded as a "resource aggregator" containing multiple arithmetic resources. Based on the above setting, DBMM characterizes the resource demand on the task side and the resource supply capacity on the center side to extract features that can be used to support the matching process.

Task requirements are proposed by the user and are a description of the amount of resources to be occupied by the submitted computational task, the desired resource state, and other elements. Among them, the amount of resources refers to the amount of arithmetic resources. Therefore, each task t can be described by a quintuple consisting of computational cores requirement C_t, storage capacity requirement S_t, transmission bandwidth requirement B_t, estimated working hours T_{tpred}, and application requirement A_t, as shown in equation (14):

$$t = \begin{bmatrix} C_t & S_t & B_t & T_{tpred} & A_t \end{bmatrix} \tag{14}$$

Each arithmetic center p can be described using a tensorial group as shown in equation (15):

$$p = \begin{bmatrix} C_p \ C_{p,\text{limit}} \ C_{p,\text{run}} \ C_{p,\text{wait}} \ S_p \ S_{p,\text{used}} \ B_p \ B_{p,\text{sed}} \ T_{p,\text{limit}} \ A_p \end{bmatrix} \tag{15}$$

where C_p denotes the total number of cores in the arithmetic center. $C_{p,\text{limit}}$ denotes the maximum number of kernels allowed to be occupied by a task. $C_{p,run}$ denotes the number of cores that are running. $C_{p,wait}$ denotes the total number of cores required by the task. S_p denotes the total storage capacity of the arithmetic center. $S_{p,\text{used}}$ indicates the used storage capacity. B_p indicates the maximum data transfer bandwidth allowed by the arithmetic center. $B_{p,used}$ indicates the occupied network bandwidth. $T_{p,limit}$ denotes the maximum computing hours allowed by the arithmetic center. Set $A_p = \{A_{appl}, A_{app2}, A_{app3}, ..\}$ indicates the application deployment of the arithmetic center.

3.2.2. Dynamic two-way matching strategy:

1) Preliminary screening. When performing dynamic bidirectional matching of task demand and resource capability, preliminary screening of the task demand model and resource capability model is first required to remove task-resource pairs whose task demand does not match the resource capability, so as to simplify the subsequent matching process. The preliminary screening constraints are shown in equation (16):

$$\begin{cases} C_t \le C_{p,\text{limit}} \\ S_t \le S_p - S_{p,\text{uscd}} \\ B_t \le B_p - B_{p,\text{uscd}} \\ T_{t,\text{prod}} \le T_{p,\text{limit}} \\ A_t \in A_p \end{cases} \tag{16}$$

2) Matching degree definition. The task-oriented matching degree mainly considers the impact of task execution in the corresponding resources on the global resource utilization, in order to ensure the utilization of global resources, it is necessary to select the resources with higher degree of similarity to the task for matching. Therefore, DBMM constructs a three-dimensional vector $\vec{t}$ (containing the computational core requirement C_t, data storage requirement S_t, and transmission bandwidth requirement B_t of the task) to represent the task requirements, as shown in equation (17):

$$\vec{t} = (C_t, S_t, B_t) \tag{17}$$

Meanwhile, the total number of cores C_p, the total storage capacity S_p, and the maximum data transfer bandwidth B_p of the computing center are constructed as a three-dimensional vector $\vec{p}$ to represent the resource capacity as shown in equation (18):

$$\vec{p} = (C_p, S_p, B_p) \tag{18}$$

The task-to-match degree $\alpha_{t,p}$ indicates the degree of similarity between task requirements and resource capabilities, and its value ranges from (0, 1), as shown in equation (19):

$$\alpha_{t,p} = S_c(\vec{t}, \vec{p}) = \frac{\vec{t} \cdot \vec{p}}{|\vec{t}| \times |\vec{p}|} \tag{19}$$

When task t is assigned to the computing center p for execution, the computational, storage, and network resource occupancy of this computing center is shown in equation (20):

$$\begin{cases} L_{t,p,\text{omp}} = \dfrac{C_{p,\text{mm}} + C_{p,\text{wait}} + C_t}{C_p} \\ L_{t,p,\text{stor}} = \dfrac{S_{p,\text{mad}} + S_t}{S_p} \\ L_{t,p,\text{et}} = \dfrac{B_{p,\text{used}} + B_t}{B_p} \end{cases} \tag{20}$$

For multiple arithmetic centers, the computation, storage, and network resource occupancy of each arithmetic center is mapped to the range of values (0, 1] using the min-max normalization method, as shown in Equation (21):

$$L' = \frac{L - L_{\min}}{L_{\max} - L_{\min}} \tag{21}$$

where L can be the computation $L_{t,p,comp}$, storage $L_{t,p,\text{stor}}$, and network resource occupancy $L_{t,p,net}$ of the arithmetic center p, while $L_{\max}$ and $L_{\min}$ represent the maximum and minimum values of multiple arithmetic centers' occupancy of a certain type of arithmetic resources. Considering the global load balancing and the load of each type of arithmetic resources, the value range of the resource-to-match degree $\beta_{t,p}$ is set to [0, 1), as shown in Equation (22):

$$\beta_{t,p} = \left\| \left(\frac{1 - L'_{t,p,\text{comp}}}{\sqrt{3}}, \frac{1 - L'_{t,p,\text{stor}}}{\sqrt{3}}, \frac{1 - L'_{t,p,\text{net}}}{\sqrt{3}} \right) \right\| \tag{22}$$

The definition of resource-wise matching degree takes into account the global load balancing factor in the min-max normalization process, and the idle degree of resources is obtained by using the vector mode after normalization, which can visually reflect the load situation of various types of resources.

DBMM defines a bi-directional composite matching degree based on task-oriented matching degree and resource-oriented matching degree, which considers and weighs the preferences of tasks and resources. The value range of the bi-directional composite matching degree $M_{t,p}$ is set to (0, 1), as shown in Eq. (23):

$$M_{t,p} = \lambda \times \left(\frac{\alpha_{t,p} + \beta_{t,p}}{2} \right) + (1 - \lambda) \times \sqrt{\alpha_{t,p} \times \beta_{t,p}} \tag{23}$$

The bi-directional composite matching degree $M_{t,p}$ is a weighted sum of the arithmetic and geometric means of the task-oriented matching degree $\alpha_{t,p}$ and the resource-oriented matching degree β_t, p to represent the trade-off between the two in terms of bi-directional consistency and bi-directional complementarity.

3) Scheduling Program Design. Due to the matching strategy, each task in the task matrix T and each resource in the resource matrix P that has been initially screened can be computed to obtain a two-way comprehensive matching degree $M_{t,p}$, and the resource with a high matching degree is more

suitable for the task, i.e., the task is assigned to the resource to obtain higher computational performance and better utilization of system resources.

The bi-directional composite matching degree $M_{t,p}$ weighs the task-oriented matching degree $\alpha_{t,p}$ and resource-oriented matching degree $\beta_{t,p}$, i.e., the trade-off between the "best-fit resource in the task perspective" and the "best-fit task in the resource perspective", and is adjusted by parameter λ. With parameters $\lambda=0$ and $\lambda=1$, Eq. (23) expresses the bi-identical consistency and bi-directional complementarity of task-oriented and resource-oriented matching, respectively. In the experiments, the value of parameter λ is 0.5, which aims to balance the bi-directional consistency and bi-directional complementarity between task-oriented matching $\alpha_{t,p}$ and resource-oriented matching $\beta_{t,p}$.

Based on the bi-directional comprehensive matching degree $M_{t,p}$, DBMM can select reasonably suitable resource-task pairings to generate efficient scheduling schemes. In generating the resource matching scheme, the resource matching is performed sequentially by prioritizing the submission time of tasks in the system. For each task, DBMM arranges it with $M_{t,p}$ of all resources in descending order to set the set of optional scheduling targets for the task, and uses $M_{t,p}$ as the basis for scheduling scheme generation. When a task has the same $M_{t,p}$ with multiple resources, the resourcewise matching value is used as the basis for the ordering. For a resource with a large resource matching degree, selecting it as the scheduling target can effectively balance the global resource load because of its high degree of idleness. If the resource direction matching degree is also the same, either one of them can be selected as the scheduling target. After the resource matching scheme for a task is determined, the DBMM feeds it back to the computing platform and dynamically updates the resource occupancy in the computing platform.

4. Research on the Integration of Scientific Research Resources of International Business Disciplines in Xiamen Institute of Technology

In order to explore the effectiveness of the proposed model of research resource integration and allocation based on distributed computing, this paper takes Xiamen Institute of Technology, a private university, as an example and analyzes the improvement of the effectiveness of research resource integration in the discipline of international business after the application of the model.

4.1. Introduction to Xiamen Institute of Technology

Xiamen Institute of Technology (XIT) is a full-time general undergraduate university approved by the Ministry of Education of the People's Republic of China and founded by Xiamen Renwen Investment and Development Co. The predecessor of Xiamen Institute of Technology of Huaqiao University, which was founded in 2009, was approved by the Ministry of Education of the People's Republic of China to be converted into Xiamen Institute of Technology (XIT) in 2015. After the transfer as an engineering college. In order to ensure the development of the college, there are many laboratory construction projects, which require a large amount of funds. Therefore, in order to overcome the difficulties of insufficient funds after the transfer, it is necessary to effectively integrate the disciplinary research resources to enhance the effectiveness of its resource utilization. This paper focuses on the research resource integration of this private college in the discipline of international business.

4.2. Scheduling Optimization Experiments for Distributed Computing Environments

This paper constructs a model for integrating and allocating scientific research resources based on Distributed Computing with Mobile Agent (DCMA), therefore, the effectiveness of the optimization method of distributed computing scheduling should be verified before the allocation of scientific research resources, i.e., the effectiveness of the proposed Dynamic Bi-directional Matching Method of Tasks and Resources (DBMM) should be explored.

4.2.1. Preparation of the computing environment. The performance experiments on the dynamic scheduling of tasks and resources for the DBMM algorithm are done on a high-performance distributed computing platform as shown in Table 1. This environment adopts the mainstream blade architecture in the market, and the peak computation value can reach 4.8 trillion times. The distributed memory system program design method based on message passing (MPD) is chosen to be used, and the function library software is MPICH 1.5.

Table 1. High-performance computing server configuration

Configuration item	Quantity	Main performance index
Computation node	32	Dell PowerEdge M000E, CPU: 8 16-core processors, 20GHz. Memory 64GB. Hard disk 320 GB-SSD. 40GB-IB card. 2 Gigabit network cards.
Management node	1	Dell PowerEdge MI-000e, CPU: four 10-core processors, the main frequency of 2.0GHz. Memory 32GB.Two 300G-SAS hard disks, supporting array. 40GB-IB card.
Memory node	1	Dell Power Vault MD3620f storage array example, cache 4GB, support cache protection. Support RAID0, 1, 3, 5, 6, 10. Each cabinet contains 12 hard disks. The actual capacity is 10 disks × IT.
Connection mode	2	Mellanox:M4001F-Infiniband switch cross block, FDR: 40Gb/s, QDR and FDR10:40 Gb/s.

4.2.2. Performance evaluation indicators. The scheduling performance evaluation metrics used in this experiment are shown below:

1) Normalized Scheduling Length (NSL). The scheduling length (SL) actually represents the shortest time to complete all tasks using a certain scheduling strategy. In order to facilitate the analysis and comparison, it needs to be normalized, i.e:

$$NSL = \frac{SL}{\sum_{t_i \in T_{CP}} \left[\min_{m=0,1,\ldots,M-1} c\left(t_i, p_m\right) \right]} \tag{24}$$

where T_{CP} denotes the set of nodes on the critical path of a directed acyclic graph (DAG).

2) Speedup ratio (S). The speedup ratio S of a parallel application is defined as:

$$S = \frac{\sum_{t_i \in T} \left[\min_{m=0,1,\ldots,M-1} c\left(t_i, p_m\right) \right]}{SL} \tag{25}$$

and $1 \le S \le M$, M denote the number of arithmetic centers contained in the distributed computing platform. T denotes the set of tasks.

3) Efficiency (E). Efficiency is defined as the proportion of time that processors actually spend on computation during the entire scheduling process:

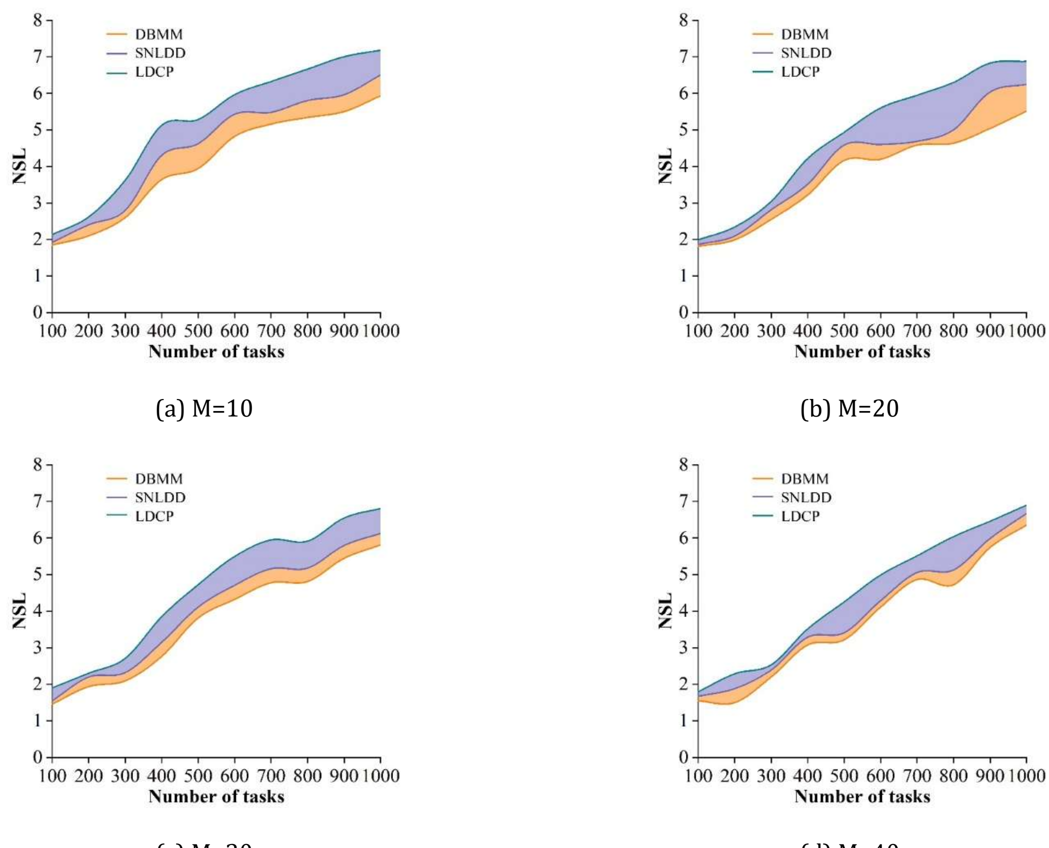
$$E = \frac{S}{M} \tag{26}$$

Not surprisingly, $1/M \le E \le 1$.

4.2.3. Experimental Procedure and Analysis of Results. Simulate parallel applications using random graphs, the generation parameters of the graphs mainly include the number of arithmetic centers: 10, 20, 30, 40, the number of tasks: 100, 200, ..., 1000, the computation cost: [0,50], the communication cost: [5,100]. Randomly generate 1000 task graphs of parallel applications, respectively use LDCP, SNLDD [23] and DBMM algorithm in this paper to calculate the scheduling scheme for each task graph, count the average standardized scheduling lengths, speedup ratios, and efficiencies, and compare and analyze the performance differences of the algorithms.

1) Normalized scheduling length. NSL is related to the number of arithmetic centers, in order to make the results valid and objective, under the condition of the same number of arithmetic centers, the average NSL of the three algorithms generating schemes with the number of computational tasks in 100, 200, ..., 1000 total 10 cases is shown in Fig. 5. The shaded portion of the figure indicates the average NSL difference between the different algorithms.

From Fig. 5, it can be seen that the average NSLs of LDCP, SNLDD and DBMM all show an increasing trend, which is consistent with the theory. In addition, the average NSL obtained by the SNLDD algorithm is significantly smaller than that of the LDCP algorithm, with a maximum difference of up to 22.78%, and is independent of the number of arithmetic centers. When the number of tasks is small, the DBMM algorithm proposed in this paper is comparable to the SNLDD algorithm, but when the number of tasks is larger than 400, the DBMM algorithm is superior to the SNLDD algorithm, which reflects the advantage of adapting to large-scale parallel applications. And when the number of computing centers is 20, the average NSL of DBMM algorithm significantly outperforms that of LDCP and SNLDD, which is 19.89% and 11.81% shorter, respectively.



(a) M=10

(b) M=20

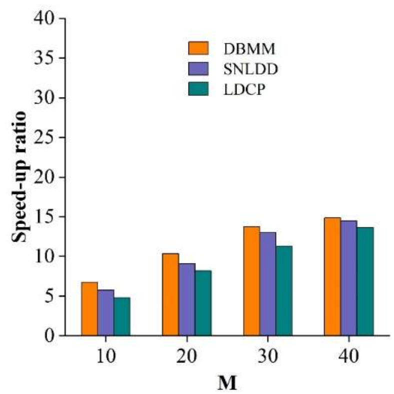
(c) M=30

(d) M=40

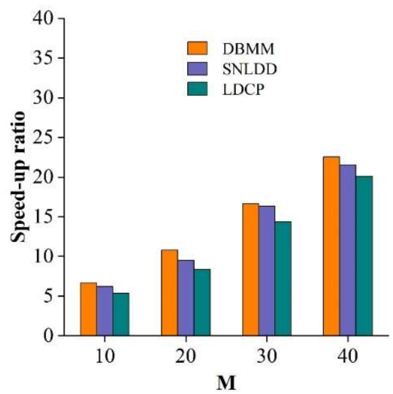
Fig. 5. Calculation results of standardized scheduling length of different algorithms

2) Acceleration Ratio. The speedup ratio is a measure of the performance improvement that can be obtained when a parallel application is executed on different numbers of arithmetic centers. Since there are 10 cases of parallel applications generated by random graphs, due to the limitation of space, only the speedup ratios obtained when scheduling with 10, 20, 30, and 40 arithmetic centers for a total of 6 task quantities of 100, 200, 400, 600, 800, and 1000 are given as shown in Fig. 6.

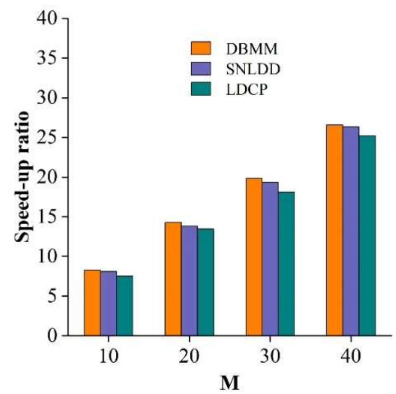
From Fig. 6, the speedup ratios of the three task scheduling algorithms, LDCP, SNLDD, and DBMM, are related to the number of tasks and the number of arithmetic centers. When the number of tasks is small, the speedup ratio is not proportional to the increase in the number of arithmetic centers, and when the number of arithmetic centers exceeds a critical value, the speedup ratio decreases with the increase in the number of arithmetic centers, which confirms the scientific assertion that “it is difficult for any program to be fully parallelized, and linear speedup ratio is only the highest goal for the pursuit of the parallel algorithms in an ideal situation”. It confirms the scientific assertion that “it is difficult for any program to be fully parallelized, and linear speed ratio is only the highest goal pursued by parallel algorithms under ideal circumstances”. From the experimental results, it can be seen that the speedup ratio of DBMM algorithm is better than that of SNLDD and LDCP, and the trend is more obvious when the number of tasks reaches 1000. With the increase of the number of arithmetic centers, the acceleration ratio of the algorithm can be improved to some extent. Overall, when the number of tasks reaches 1000, the acceleration ratio of DBMM algorithm can be maximally improved by 19.77% and 9.26% compared with LDCP and SNLDD, respectively, which can achieve the effect of shortening the running time of the parallel program and improving the computational performance of the system.



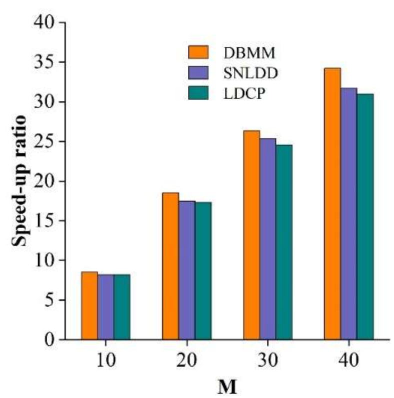
(a) The number of tasks is 100



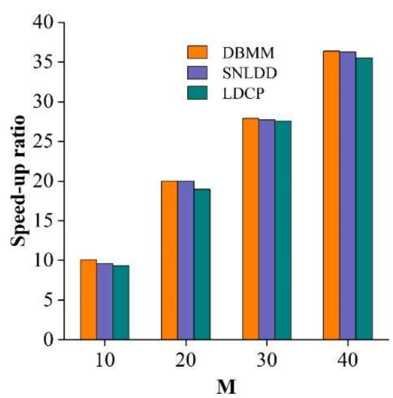
(b) The number of tasks is 200



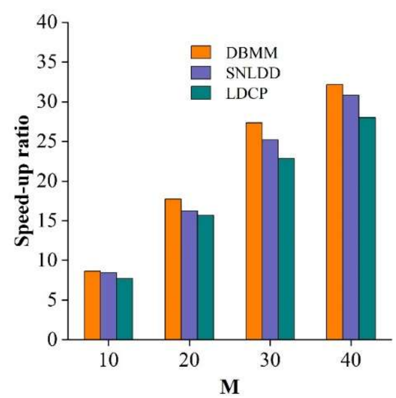
(c) The number of tasks is 400



(d) The number of tasks is 600



(e) The number of tasks is 800

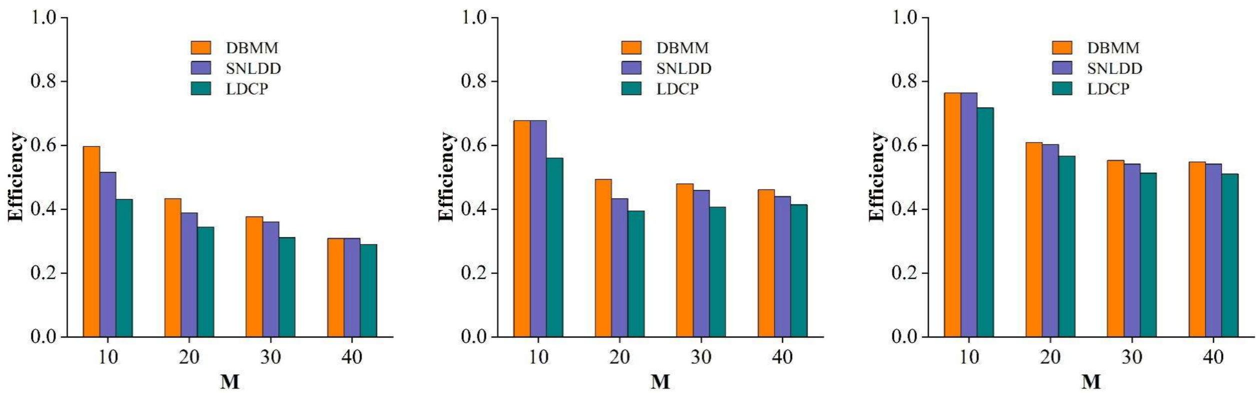


(f) The number of tasks is 1000

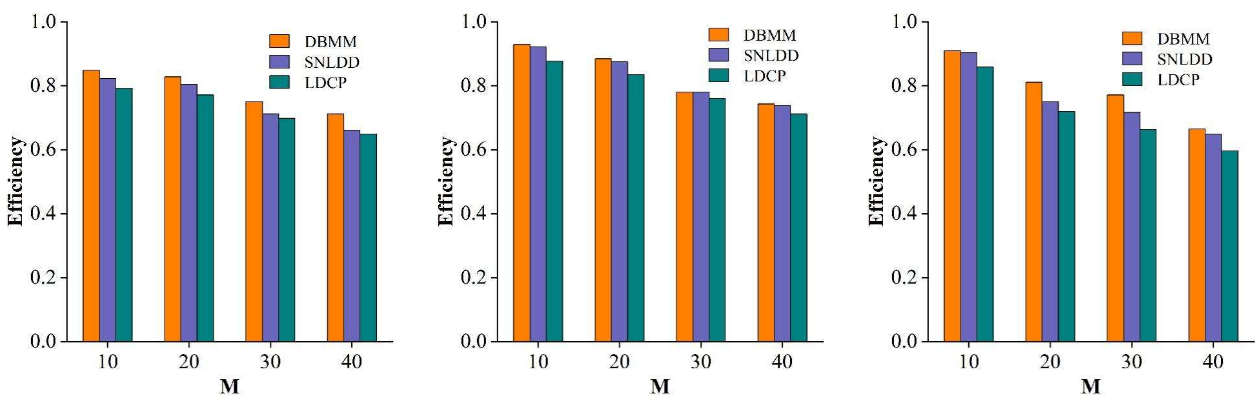
Fig. 6. Calculation results of speed up ratio of different algorithms

3) Efficiency. Efficiency reflects the utilization of computing resources of the computing center by the parallel application scheduling process, and its level directly determines the advantages and disadvantages of the scheduling scheme. According to equation (26), the efficiency is linearly related to the acceleration ratio, so using the same experimental method described above, the efficiency calculation results of different algorithms are shown in Figure 7.

When the problem size is small, the efficiency is low, but when the number of tasks increases, the efficiency increases, which is due to the fact that the arithmetic center needs to compute more tasks, so the time required for coordinating the communication work of the arithmetic center becomes relatively less, which is in line with the actual situation. The experimental results show that the average computational efficiency ratio of DBMM algorithm is improved by 10.74% and 3.72% compared to LDCP and SNLDD, respectively, which can reduce the waste of resources in the scheduling process of parallel applications.



(a) The number of tasks is 100 (b) The number of tasks is 200 (c) The number of tasks is 400



(d) The number of tasks is 600 (e) The number of tasks is 800 (f) The number of tasks is 1000

Fig. 7. Efficiency calculation results of different algorithms

4.3. Scientific research resources integration experiment

In order to prove the effectiveness of the research resource integration and allocation model based on mobile Agent distributed computing proposed in this paper, an experiment is needed. The experimental object is selected as 6834 categories of scientific research resources of international business disciplines in Xiamen Institute of Technology, and 800 categories of scientific research resources are selected for integration, and the experimental results are tested and analyzed by relevant test methods. The method of this paper and the gray correlation analysis method are respectively used to carry out the experiment of scientific research resources integration and analysis. Based on the obtained distributed calculation results, the probability of integration of different scientific research resources under the statistical analysis of the 2 different methods is analyzed in comparison with the actual probability value, and the results of the comparison of the probability of integration of scientific research resources are shown in Figure 8.

Analysis of Figure 8 shows that the probability of scientific research resource integration using the model of this paper coincides with the actual value, mainly because the model of this paper can first calculate the matching probability of different scientific research resource integration processes, extract the characteristics of scientific research resource integration, calculate the number of basic faculties of scientific research resource integration, and then carry out the analysis of scientific research resource integration based on it, which makes the method of this paper to analyze the probability of scientific research resource integration of the international business discipline coincide with the actual statistical results. The method of this paper analyzes the probability of scientific research resources integration in international business disciplines, which is consistent with the actual statistical results and lays the foundation for the further realization of scientific research resources integration in international business disciplines.

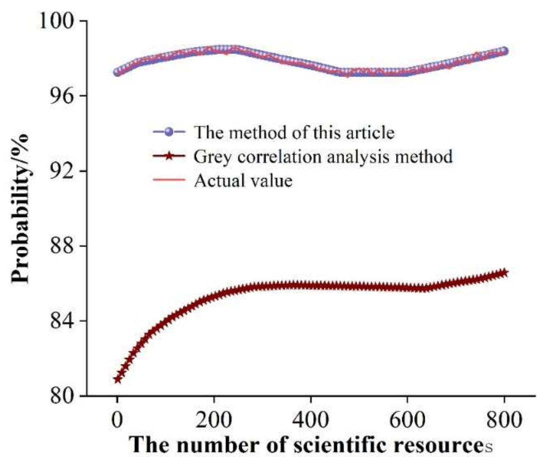


Fig. 8. Comparison of probability of scientific research resource integration

To further justify the use of this paper's method to fit the analysis of the process of integrating scientific research resources in the discipline of international business, the residuals of the correlation test are used to initially determine the goodness of fit, and the formula for calculating the goodness of fit is given using equation (27):

$$M_{t,p} = \lambda \times \left(\frac{\alpha_{t,p} + \beta_{t,p}}{2} \right) + (1-\lambda) \times \sqrt{\alpha_{t,p} \times \beta_{t,p}} \tag{27}$$

where new represents the coefficient of determination, y represents the degree of equation fit, and Q represents the residual sum of squares.

The goodness of fit of research resource integration analysis under the comparison of 2 different methods is shown in Figure 9.

Analyzing Figure 9, it can be seen that the goodness of fit of the method of this paper is better than the gray correlation analysis method, which is mainly because the method of this paper is mainly used to obtain the task and resource characteristics of the scientific research resource integration characteristics of the discipline of international business, and to calculate the bidirectional composite matching degree between the main scientific research resource integration, based on which scientific research resource integration analysis is carried out, which makes the method of this paper better than the gray correlation analysis method, and makes the method of this paper better than the gray correlation analysis method. The fit of this paper's method for scientific research resource integration is better.

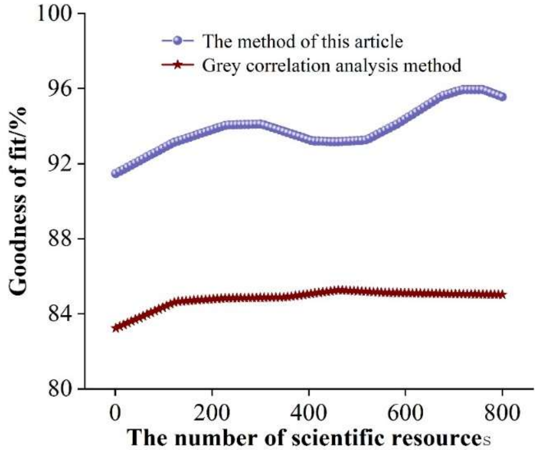


Fig. 9. Comparison of goodness of fit was analyzed by different methods

Analytical experiments on the integration of scientific research resources in the discipline of international business were conducted using the methods of this paper and gray correlation analysis, respectively. The robustness (%) of the 2 different methods for research resource integration is compared, and the results of the robustness comparison are shown in Figure 10.

Analysis of Figure 10 shows that the robustness of this paper's method is better than the gray correlation analysis method when using this paper's method for college students' education resource integration. This is mainly because this paper's method optimizes the efficiency of distributed computing by analyzing the matching relationship between tasks and resources, thus realizing the global optimization and dynamic matching of the process of research and education resource integration, which makes the robustness of this paper's method for research resource integration superior. In summary, it can be seen that the global integration and allocation model of scientific research resources based on distributed computing constructed in this paper can effectively improve the overall effectiveness of scientific research resources integration in international business disciplines in private schools.

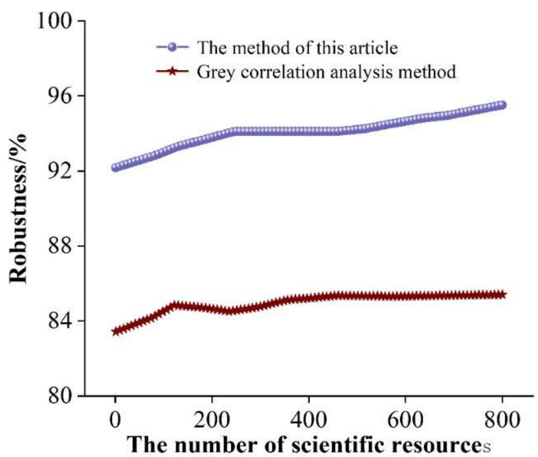


Fig. 10. Comparison of robustness of different integration methods

5. Conclusion

In this paper, we design a dynamic bidirectional matching method (DBMM) for tasks and resources oriented to distributed computing, and construct a global integration and dynamic allocation model of scientific research resources based on mobile agents, so as to realize the efficiency improvement of scientific research resources integration in the discipline of international business in private colleges and universities.

In this paper, the DBMM algorithm and the average NSL of LDCP and SNLDD algorithms show an increasing trend. Among them, the average NSL of SNLDD algorithm is significantly smaller than that of LDCP algorithm, and the maximum difference can reach 22.78%. When the number of tasks is greater than 400, the DBMM algorithm is significantly better than the SNLDD algorithm. And compared with LDCP and SNLDD algorithms, the average NSL of DBMM algorithm is shortened by 19.89% and 11.81%, respectively. As for the speedup ratio, DBMM algorithm also outperforms SNLDD and LDCP algorithms, and achieves the maximum improvement of 19.77% and 9.26% when the number of tasks reaches 1000, respectively. In addition, the average computational efficiency of DBMM algorithm is improved by 10.74% and 3.72% over LDCP and SNLDD, respectively. It shows that the DBMM algorithm proposed in this paper can shorten the running time of the parallel program, improve the computational performance of the system, and reduce the waste of resources in the scheduling process.

Xiamen Institute of Technology is selected to conduct an experiment on research resource integration in international business discipline. The experimental results show that the global integration and dynamic allocation model of scientific research resources proposed in this paper can accurately describe the correspondence between the integration of scientific research resources, with less analytical error and better robustness than the gray correlation analysis method, which can effectively improve the overall effectiveness of scientific research resources integration in international business disciplines.

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References

[1] Liu, X. (2020). The development of private universities in socialist China. Higher Education Policy, 33(1), 1-19.

[2] Wang, J., Yang, M., & Maresova, P. (2020). Sustainable development at higher education in China: A comparative study of students’ perception in public and private universities. Sustainability, 12(6), 2158.

[3] Dwivedi, R. K. (2022). Analysing The Quality Of Public And Private Higher Educational Institution In China. Journal of Pharmaceutical Negative Results, 4840-4851.

[4] Garwe, E. C. (2016). Increase in the demand for private higher education: unmasking the “paradox”. International Journal of Educational Management, 30(2), 232-251.

[5] Daniels, J. D., Radebaugh, L. H., & Sullivan, D. P. (2019). International business: Environments and operations. Pearson.

[6] Kolk, A., Rivera-Santos, M., & Rufín, C. (2018). Multinationals, international business, and poverty: A cross-disciplinary research overview and conceptual framework. Journal of International Business Policy, 1(1), 92-115.

[7] LeClair, D. T., Clark, R., Ferrell, L., & LeClair, D. (2021). Ethics in international business education: Perspectives from five business disciplines. In Teaching International Business (pp. 43-71). Routledge.

[8] Hamilton, L., & Webster, P. (2018). The international business environment. Oxford University Press.

[9] Chang, S. J., Van Witteloostuijn, A., & Eden, L. (2020). Common method variance in international business research. Research methods in international business, 385-398.

[10] Meyer, K. E. (2017). International business in an era of anti-globalization. Multinational Business Review, 25(2), 78-90.

[11] Michailova, S., & Tienari, J. (2014). What's happening to international business? University structural changes and identification with a discipline. Critical perspectives on international business, 10(1/2), 51-64.

[12] Poulis, K., & Poulis, E. (2018). International business as disciplinary tautology: An ontological perspective. Academy of Management Perspectives, 32(4), 517-531.

[13] Shanableh, A., Aderibigbe, S., Omar, M., & Shabib, A. (2022). Challenges and opportunities of multi-disciplinary, inter-disciplinary and trans-disciplinary research. Higher Education in the Arab World: Research and Development, 311-325.

[14] Chou, W. H., & Wong, J. J. (2015). From a disciplinary to an interdisciplinary design research: developing an integrative approach for design. International Journal of Art & Design Education, 34(2), 206-223.

[15] O'Rourke, M., Crowley, S., & Gonnerman, C. (2016). On the nature of Cross-disciplinary integration: a philosophical framework. Studies in history and philosophy of science part C: studies in history and philosophy of biological and biomedical sciences, 56, 62-70.

[16] Bocconcelli, R., Carlborg, P., Harrison, D., Hasche, N., Hedvall, K., & Huang, L. (2020). Resource interaction and resource integration: Similarities, differences, reflections. Industrial Marketing Management, 91, 385-396.

[17] Wu, Y., Xu, L., Lin, J., & Ghani, M. I. (2023). Subject embedding, relationship interaction, and resource integration: the value co-creation mechanism in rural communities. Systems, 11(10), 507.

[18] Lone, A. N., Mohd-Any, A. A., & Mohd Salleh, N. A. (2021). Social media agencies and clients: A resource integration approach. Journal of Business-to-Business Marketing, 28(4), 369-394.

[19] Rafi, M., JianMing, Z., & Ahmad, K. (2020). Digital resources integration under the knowledge management model: an analysis based on the structural equation model. Information Discovery and Delivery, 48(4), 237-253.

[20] Sund, K. J., Barnes, S., & Mattsson, J. (2018). The IPOET matrix: measuring resource integration. International Journal of Organizational Analysis, 26(5), 953-971.

[21] Yashar Pourardebil Khah, Mirsaeid Hosseini Shirvani & Homayun Motameni. (2025). Correction: A hybrid machine learning approach for feature selection in designing intrusion detection systems (IDS) model for distributed computing networks. The Journal of Supercomputing(2),419-419.

[22] Song Yao, Wang Liang, Xiao Limin, Shen Runnan, Wang Jinquan & Zhang Chenhao. (2023). Dynamic two-side matching of tasks and resources in wide-area distributed computing environments. The Journal of Supercomputing(9),10208-10231.

[23] Nirmeen A. Bahnasawy,Fatma Omara,Magdy A. Koutb & Mervat Mosa. (2011). Optimization procedure for algorithms of task scheduling in high performance heterogeneous distributed computing systems. Egyptian Informatics Journal(3),219-229.