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A Distributed Computing Solution for Integrating International Business Research Resources in Private Universities: The Case of Xiamen University of Technology

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Abstract As an applied discipline with strong intersectionality and outstanding practicality, the scientific research activity of international business involves diversified data sources and heterogeneous resource types. Aiming at the problem of uneven allocation of scientific research resources in international business discipline in private universities, this paper constructs a system of scientific research resource integration and performance enhancement based on distributed computing. The research adopts the dominant resource fair distribution algorithm (DRF) instead of the traditional load balancing algorithm, acquires research resources through submission, cooperation and other methods, establishes a unified authoring standard for resource processing, and designs a four-layer logical structure that includes end users, portal sites, registration centers and resource sites. Experimental results show that under the condition of 16,000 resources, the system integration time is from 25.031 seconds to 28.754 seconds, and the throughput reaches 562 to 693 per second, which improves the utilization rate compared with the traditional algorithm to the range of 20% to 85%, and effectively avoids more than 50% of high load fluctuation. The study shows that the DRF algorithm significantly improves the load unevenness problem in the process of multi-resource allocation, realizes the relative balance among cluster nodes, and effectively improves the resource utilization and processing efficiency of the scientific research resource integration system of international business disciplines.

Index Terms Distributed computing, research resource integration, dominant resource fair allocation algorithm, load balancing, resource utilization, international business discipline

I. Introduction

Private colleges and universities are higher education institutions run by social forces, which have the characteristics of running schools independently and have their own goals and ways of running schools [1]. With the continuous development of China's higher education, private colleges and universities are gradually emerging in teaching, research and other aspects [2]. The discipline of international business, as an important course in the education of private colleges and universities, has received more and more attention and emphasis in recent years [3]. The discipline of international business is a disciplinary category involving international trade, international markets, multinational corporations and other fields [4]. With the acceleration of globalization, more and more enterprises are involved in international trade and need professional talents for management and business expansion. Therefore, the discipline of international business has emerged [5], [6].

However, due to the relatively limited scientific research resources of private universities, there are gaps in running funds, teaching staff and scientific research equipments relative to public universities, resulting in the conditions of scientific research in the discipline of international business in private universities are not as good as those in public universities [7]-[9]. This lack of resources to a certain extent limits the ability of private university students to carry out scientific research activities in international business disciplines, which is not conducive to the improvement of teaching effectiveness and talent cultivation [10], [11]. In this context, private colleges and universities take the path of scientific research resource integration to improve the effectiveness of resources in order to avoid their own shortcomings in scientific research resources [12], [13]. Research resource integration implies that researchers integrate various resources, including literature databases, experimental equipment, talents, etc., in order to enhance the efficiency and quality of research [14]. It can help researchers avoid duplication of labor, reduce the waste of resources, and improve the output efficiency of research results.

This study adopts the research method combining theoretical analysis and empirical verification to construct a scientific research resource integration system under distributed computing environment with Xiamen Institute of

Technology as the empirical object. Firstly, through literature research and theoretical analysis, the core elements and technical paths of scientific research resource integration are clarified; then the resource scheduling mechanism based on the dominant resource fair allocation algorithm is designed to solve the load balancing problem under the scenario of multi-resource types; then the complete technical architecture including resource acquisition, processing, storage and service is constructed to realize the full life-cycle management of scientific research resources; finally, the system is verified through comparative experiments to assess the efficiency and performance of resource integration, and to evaluate the efficiency and performance of the system in the distributed computing environment. Finally, the system performance is verified through comparative experiments to evaluate the efficiency of resource integration and performance enhancement.

II. Research Resources Integration and Efficiency Enhancement Exploration

II. A.Access to scientific research resources

Data resources are the basis for the normal operation and value of the platform. Xiamen University of Technology, as a research-oriented comprehensive university, generates a large amount of scientific research data in business disciplines every year, and when building the open research data platform, the construction of scientific research resources in business disciplines is taken as an important part, and the ways of obtaining the resources are mainly categorized into the following ones:

II. A. 1) Method of Presentation

Xiamen Institute of Technology (XIT) takes the data resources generated in the process of scientific research as part of the scientific research results, and stipulates that the research subjects in the institution are required to submit the project results and related data as a prerequisite for the completion of the project at the end of the scientific research funding program. Driven by the relevant policies, Xiamen Polytechnic University has effectively accumulated and managed scientific research data resources within the institution by utilizing the scientific research results of the research subjects, and the data set submitted by Xiamen Polytechnic University as the scientific research subject within the current platform has reached a very desirable state, which better realizes the access to scientific research resources of business disciplines within the institution.

II. A. 2) Modalities of cooperation

As a comprehensive research data resource integration and service platform, its internal resources are limited, so cooperation with external organizations is particularly important to greatly expand the sources of data resource acquisition, Xiamen Polytechnic University Open Research Data Platform has acquired a large number of data resources external to the institution in a cooperative manner.

II. A. 3) Other modalities

According to the introduction of the platform, it can be learned that in addition to encouraging scientific research subjects to submit data resources on their own, the platform does not rule out the possibility of collecting data resources outside the organization in a targeted manner through transactions, proactively expanding the source of access to the platform's resources, increasing the amount of data resources stored, and promoting the diversification of data resources.

II. B.Handling of scientific research resources

The processing of scientific research resources in business disciplines is based on the acquisition of scientific research resources in business disciplines, and the heterogeneous data are processed with unified authoring standards in order to get the data that meets the standardized format of the platform. Xiamen Polytechnic University Open Research Data Platform tends to receive complete and accurate data sets that have been processed and converted according to the requirements, and it is also willing to provide assistance to scientific research subjects in managing the stored data, such as cleaning, standardizing, classifying and updating. The processed data resources will be centrally stored and loaded into the data platform. Data file is the smallest granularity entity object in the whole data resource system, which is matched with the files in different formats in the source data, such as documents, tables, pictures and other common formats. At present, the establishment of the association service provided by the platform relies on the storage mode of data files, and the interrelated data files are put into the same data set, so as to ensure the accuracy of association. In addition, the resource cataloging system of the platform is extended on the basis of DDI, which can be divided into two categories, one with universal cataloging standards and the other with discipline-specific cataloging standards, with strong scalability and high flexibility.

II. C.Scientific research resource integration system design

II. C. 1) Selection of technology realization tools

In the system design, especially taking into account the constraints of network bandwidth and comprehensive efficiency of the system, the data to be transmitted to carry out a comprehensive selection of the best, the really useful results and valuable suggestions to return to the user. In this regard, the use of contemporary data mining, intelligent search and intelligent agents and other technologies is very useful, such as in the design of resource retrieval algorithms, preferential delineation of those closer to the appropriate amount of resources that may contain the appropriate amount of resources to carry out the initial retrieval and optimized screening of the results presented to the user at the same time to provide the relevant information to help the study, according to the learner's behavior (eg, to open the results of the resource, to receive or reject), the learning suggestions, the second retrieval and the initial retrieval. Learning suggestions, the relevance of the second retrieval to the initial retrieval, etc.), and each time the results retrieved from each resource site should be intelligently sorted after weighted comprehensive evaluation (mainly considering relevance, popularity, timeliness, authority, etc.), in an effort to achieve complete, accurate and efficient search. The above analysis of the main technical means used in this system, in the process of network development, we will also be based on actual needs at any time, such as JSP, ASP, HTML, Java, Visual Studio.NET, Delphi and other commonly used technologies, with the space, it can not be enumerated here. In the hardware conditions, we develop and design the application of the intel architecture of the PC as a server, is a local area network within the scope of the experimental research. After the successful development of the system, the actual application can be completely flexible according to the needs of choice.

II. C. 2) Logical structure

(1) End-users: interact with the system through the portal site, register their basic personal information with the system, and enjoy the services provided by the system within the scope permitted by the system rules, with three specific roles: students, teachers, and administrators. The focus here is on students, who have age, gender, living area, family, economic status, school, grade, hobbies, study habits, and other factors that can influence the demand for resources. Their e-learning behaviors (online location, starting and ending time, specific content of learning, recognition of the system's help, goal-directedness of learning, number and types of resource applications, etc.) will be subject to the system's comprehensive tracking, timely assessment, and helpful guidance.

(2) Portal site: the interface for users to interact with the system, responsible for receiving user registration, opening the system access rights of qualified users, verifying the user's request to enter the system, analyzing the user's identity and personality, providing feedback on the user's evaluation results and guidance, responding to the user's requests for a variety of resources and services, searching for and activating the corresponding Web Service to the registration center to appropriately provide services for the user, and evaluating the other sites (registration center and resource center). Evaluate the situation of other sites (registration center and resource sites) and make timely adjustments. The portal site is the communication window of the system presented to the users, and all the resource integration, user security control and multi-site joint operation are first realized through this site.

(3) Registration Center: The registration center in the system is a private internal registration center, which only responds quickly to the Web Service release and search requests of legitimate users (from portal sites, resource sites, legitimate third-party applications, etc.) within the permitted scope of the system; for the part of the Web Service that is ripe for being fully opened up to the society, we can use the commercial public registration center to carry out registration and search services. Center for registration and search services.

(4) Resource site: Respond to direct resource requests from portal sites and legitimate users, conduct intelligent resource search according to internal rules, feed back the optimized set of suitable search results (including basic attribute annotation information and relevant evaluation information of the resources), and provide the final resources when needed, and dynamically, proactively, and objectively evaluate the resources in this site.

II. D.Performance Improvement Based on Equitable Resource Allocation Algorithm

The traditional load balancing algorithm in the above section is based on the load balancing tool processing the client's requests on the server side to achieve load balancing. But the dataset needs to access the load balancing tool at the same location, and the aggregated congestion formed by a large number of request operations for the load balancing tool may lead to serious performance problems. The users of an educational organization are scattered across the country and all the requests need to pass through a single load balancing tool, unexpected packet loss leads to multiple inefficient retransmissions and network latency. Traditional load balancing algorithms have excellent performance when targeting single resource type scenarios but perform poorly when faced with multi-resource type scenarios, after reviewing the relevant information, this paper decides to use the Dominant Resource Fair Distribution Algorithm to achieve this. The dominant resource fair allocation algorithm (DRF) is a generalized multi-resource max-min fair resource allocation strategy. Two concepts, dominant resource and dominant share, are mainly proposed. The dominant resource is the resource that has the largest share among all the required resources in the task scheduling process. For example, CPU is the dominant resource of a task in computation-demand intensive tasks, memory and disk are the dominant resources of a task in storage-demand intensive tasks, and bandwidth is the dominant resource of a task in input-output frequent tasks. Dominant share refers to the proportion of dominant resources among all the resources that the task has been given. The dominant resource fair allocation algorithm analyzes the share of dominant resources in different types of tasks and prioritizes the tasks with the lowest share of resources. The main idea of the algorithm is to maximize the benefits and maintain a balance in resource allocation.

The application of the dominant resource fair allocation algorithm in the system is to allocate resources fairly in multi-resource scenarios, which can effectively avoid inefficient retransmissions and network delays. For example, if only the memory resources and CPU resources of the platform are considered, then assume that the platform has a total of 36 GB of memory and 18 cores of CPU resources, which are recorded as <18RAM,9CPU>, and the smallest resource unit spent by user A is <1RAM,3CPU>, and the smallest resource unit spent by user B is <4RAM,1CPU>. If the platform allocates the resources for executing the task to each user, then user A needs to consume 1/36 of the total resources for executing the task in memory and 1/6 of the CPU, and user B needs to consume 2/18 of the total resources for executing the task in memory and 1/18 of the CPU. Comparing the ratio of memory to CPU in user A, we can see that the dominant share of user A is CPU, while comparing the ratio of memory to CPU in user B, we can see that the dominant share of user B is memory. At this point, the dominant share of user A is 1/6 and the dominant share of user B is 2/18.

DRF policy assignment can be computed by the following algorithm.Let the environment where a is the number of tasks assigned to user A and b is the number of tasks assigned to user B. For:

$$\mathrm{Max}(a,b)\left(Maximum\ allocation\right) \tag{1}$$

$$a+4b \le 18\left(Memory\ limit\right) \tag{2}$$

$$3a+b \le 9 \le CPU\left(CPU\ limit\right) \tag{3}$$

$$\frac{a}{3}=\frac{2b}{9}\left(Dominant\ share\ balance\right) \tag{4}$$

Solving the above equation gives $a=2$ and $b=3$. User A gets 2GB of RAM and 6 CPUs, and user B gets 12GB of RAM and 3 CPUs.It is worth noting that the DRF policy does not balance the dominant share of users frequently. When the total demand for a user's tasks is satisfied, it means that the user does not want more tasks, implying that the excess resources can be distributed among other users. In short, the DRF policy is to maximize the smallest dominant share resource among all users.

The dominant share of user A is smaller than the dominant share of user B, the DRF policy will adjust the resources to equalize the distribution of resources and prioritize the allocation of resources to user A. Based on the above calculation, the thesis will define the dominant resource fair allocation algorithm as follows and propose a formalized description method.

Let there be k available resource and b task requests in the environment, then the set of available resource types is $\mathrm{Re}source=\{r_1,r_2,\ldots,r_k\}$ and the set of task types is $Mission=\{m_1,m_2,\ldots,m_b\}$. The total number of resources in the environment at this point in time can be represented by the vector as $\mathrm{Re}source_{total}\left(rt_1,rt_2,\ldots,rt_k\right)$.

The resources required for task execution in the cluster are set as a vector $\mathrm{Re}sourceNeed_{m_i}$, which can be represented by Equation (5):

$$\mathrm{Re}sourceNeed_{m_i}=(mr_1,mr_2,\ldots,m_k)\ (i\in\{1,2,\ldots,b\}) \tag{5}$$

The share of resources required for task m_s is given by equation (6):

$$Share_{m_s}=\frac{\mathrm{Re}sourceNeed_{m_s}}{\mathrm{Re}source_{total}}=\left(\frac{mr_1}{rt_1},\frac{mr_2}{rt_2},\ldots,\frac{mr_n}{rt_n}\right)(s\in\{1,2,\ldots,b\}) \tag{6}$$

The dominant resource $Do\min at\,\mathrm{Re}source_{m_s}$ for the computational task m_s is represented by Equation (7):

$$\begin{cases} Share_{m_s}[x] = Max(Share_{m_s}[i])\ (i, x \in \{1, 2, \ldots, k\}) \\ DominatResource_{m_s} = r_x \end{cases} \tag{7}$$

Let the resources that have been allocated to each task be $Allocated_{m_s}$, and $Allocated_{m_s}$ be represented by Equation (8):

$$Allocated_{m_s} = (ar_1, ar_2, \ldots, ar_n)\ (s \in \{1, 2, \ldots, b\}) \tag{8}$$

Calculation of the dominant share $DominatShare_{m_s}$ of the task m_s can be expressed by calculating equation (9):

$$DominatShare_{m_s} = \frac{Allocated_{m_s}[DominatResource_{m_s}]}{Resource_{total}[DominatResource_{m_s}]} \tag{9}$$

The main idea of the dominant resource fair allocation algorithm is to accurately calculate the dominant resources and dominant shares based on the requested resource vectors of different tasks. In addition to comparing the dominant share of each task, it will also prioritize the tasks with lower dominant shares. Therefore, the allocation principle of the dominant resource fair allocation algorithm also needs to satisfy the formula (10):

$$\begin{cases} \sum_1^m Allocated_{m_i} \le Resource_{total}\ (i \in \{1, 2, \ldots, b\}) \\ DominatShare_{m_1} \approx DominatShare_{m_2} \approx \cdots \approx DominatShare_{m_b} \end{cases} \tag{10}$$

III. Empirical analysis

III. A. Subjects of study

This paper selects Xiamen Institute of Technology (XIT), formerly known as Xiamen Institute of Technology of Overseas Chinese University (XIT), an independent college jointly founded by Overseas Chinese University (OCTU) and Jindi Group in 2009, which was approved by the Ministry of Education of the People's Republic of China (MOE) in April 2015 to become a private general undergraduate college and officially renamed XIT. The school adheres to the school motto of “Be clear-minded, be knowledgeable, cultivate oneself, and act vigorously”, implements the cultivation mode of “liberal arts education + professional education”, and is committed to cultivating high-quality applied talents with innovative spirit and practical ability.

III. B. Comparative analysis of algorithms

This experiment creates a data center, which includes 200 Host physical machines. At the same time, 200 virtual machines were created, and the parameter configuration of the virtual machines is shown in Table 1.The experiment set up 2 types of business discipline research resource integration tasks, and their parameter configurations are shown in Table 2.

Table 1: Parameter configuration of the virtual machine

Parameter name	Parameter value
Instruction Length/(MIPS)	10000
Disk /MB	55000
RAM / MB	4000
Bandwidth	4000
Number of cpus	4

Table 2: Cloud task configuration

Parameter name	Task 1	Task 2
Instruction Length/(MIPS)	3000	400
Required memory /MB	40	400
Task length /MB	1000	1000
Output length /MB	10000	10000

In the simulation process of comparing with the traditional load balancing algorithm 6000 cloud tasks (containing 2500 cloud tasks 1 and 3500 cloud tasks 2) and 7000 cloud tasks (containing 3000 cloud tasks 1 and 4000 cloud tasks 2) are created for simulation experiments respectively. Fig. 1 represents the average CPU utilization of each VM during the execution of tasks when the task volume is 6000. Figure 2 represents the average memory utilization of each virtual machine during the execution of tasks when the task volume is 6000. Figure 3 represents the average CPU utilization of each virtual machine during the execution of the task when the task volume is 7000. Figure 4 represents the average memory utilization of each virtual machine during the execution of the task when the task volume is 7000. The above experimental results describe the average utilization of CPU business discipline scientific research resources and memory business discipline scientific research resources on the virtual machines in the cluster during the execution of tasks for the 2 sets of experiments, respectively. The experimental results reflect that using the traditional load balancing algorithm to allocate business discipline research resources, the load fluctuates greatly among the VMs in the cluster during task execution, and the utilization rate is usually above 50%. And from Figures 3 and 4, it can be seen that when the overall load of the cluster is high, using the traditional load balancing algorithm to allocate business discipline research resources is more likely to produce a situation in which the nodes in the cluster run out of business discipline research resources, which is easy to cause downtime. When using the DRF algorithm to allocate scientific research resources in business disciplines, the load fluctuation among virtual machines in the cluster is small during the task execution, and the utilization rate is usually above 20%~85%, and when the overall load of the cluster is high, there are very few cases of running out of scientific research resources in business disciplines in the cluster, which shows that the DRF algorithm can improve the situation of uneven load generated by traditional load-balancing algorithms during the allocation of scientific research resources in business disciplines effectively. This shows that the DRF algorithm can effectively improve the situation of uneven load generated by traditional load balancing algorithms in the process of scientific research resources allocation in business disciplines, and achieve the purpose of relatively balanced load of each node in the cluster, thus enhancing the fairness in the process of multi-resource allocation, and effectively improving the utilization rate of resources in the international business disciplines scientific research resources integration system.

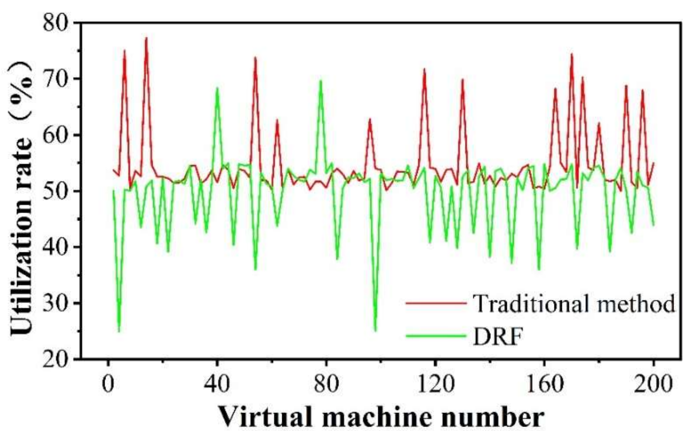

Figure 1: CPU utilization (Task volume:6000)

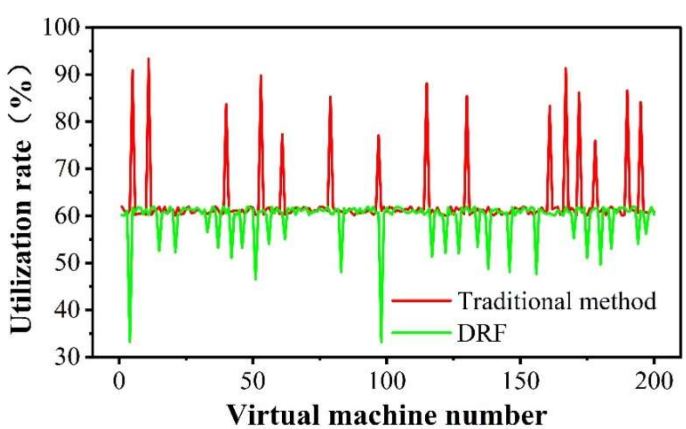

Figure 2: Memory utilization rate (Task volume:6000)

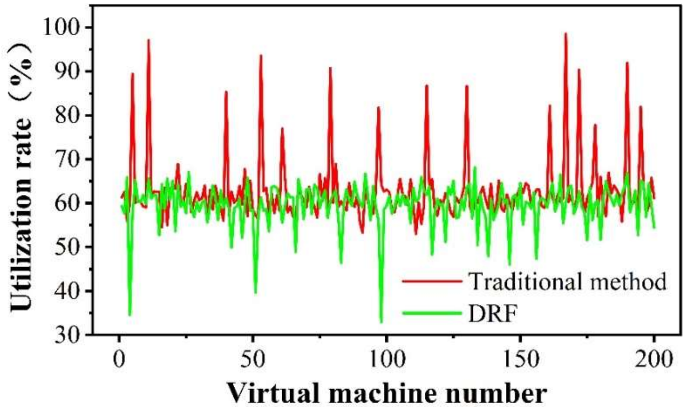

Figure 3: Memory utilization rate (Task volume:7000)

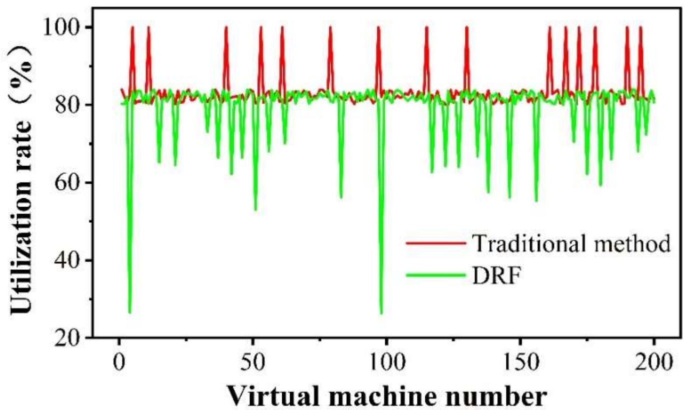

Figure 4: Memory utilization rate (Task volume:7000)

III. C. System test detection analysis

III. C. 1) Experimental environment

The specific description of the development platform for the representation layer of the Web service and call service system is shown below:

(1) Operating system: Windows XP professional + NET. FRAMEWORK 3. 2
(2) Development environment: visual studio. NET 2013
(3) Development language: Java, C#
(4) Database: SQL Server 2015
(5) Application Server: Microsoft S4 9
(6) Related technologies: ADO.NET, Web SERVICES

III. C. 2) Content of testing

In order to verify the effectiveness and feasibility of the system, the proposed system is evaluated in terms of integration efficiency, throughput and scalability for the scientific research resources of international business disciplines in Xiamen University of Technology (XUIT), and a total of 20 sets of 15 times each of the integration system performance index data are obtained.

III. C. 3) Efficiency of resource integration

Table 3 shows the statistically derived measurements of the integration time of the system under different resource amounts. As can be seen from Table 3, the integration time of the system decreases with the increase of the number of resources, and the processing speed of multiple resources is accelerated by establishing a fair resource allocation algorithm, so the decrease is smaller and the fluctuation of the speed indicator is smoother. Although the time spent at the maximum number of resources reached 28.754s, the system still meets the practical application requirements, and the integration efficiency can satisfy the research resource needs of the students majoring in international business disciplines in Xiamen University of Technology.

Table 3: Resource integration duration statistics table(s)

Quantity of resources	1000	4000	9000	16000	Quantity of resources	1000	4000	9000	16000
1	3.116	8.375	15.229	28.285	11	4.458	8.585	15.275	27.377
2	4.705	7.481	15.832	25.031	12	3.318	8.233	15.287	28.754
3	4.359	8.926	17.544	26.289	13	3.107	8.714	16.797	25.058
4	3.192	7.681	16.25	27.92	14	4.021	7.549	16.126	27.555
5	3.945	8.253	16.405	26.296	15	3.691	7.221	15.43	26.226
6	3.111	8.935	15.852	28.516	16	4.077	7.077	15.714	27.609
7	3.832	7.681	15.666	25.467	17	3.685	8.822	17.253	27.7
8	3.053	8.758	16.769	27.571	18	3.814	7.895	17.737	26.978
9	3.593	7.295	16.775	28.743	19	3.061	8.479	16.145	26.675
10	3.865	8.879	17.6	25.928	20	4.879	8.218	15.592	26.638

III. C. 4) Throughput

This evaluation metric focuses on evaluating the amount of data integrated by the system per unit of time under the premise of multi-resource input. Under the action of resource fair allocation algorithm, the input resource volume is made to rise, and the system throughput is solved according to the final resource volume and time duration, and the system throughput is shown in Table 4. The results show that the system throughput grows relatively slowly when the amount of scientific research resources is small, and when the amount of scientific research resources in business disciplines is large, the system dramatically improves the throughput through the business process, business decomposition, business module services, and business discipline scientific research resource integration module based on resource attribute fields, so that a large number of scientific research resources in business disciplines are effectively processed and integrated.

Table 4: System throughput pcs/s

Quantity of resources	1000	4000	9000	16000	Quantity of resources	1000	4000	9000	16000
1	257	473	528	654	11	389	468	593	607
2	374	488	567	569	12	250	478	509	671
3	281	496	553	651	13	306	479	467	606
4	370	485	551	642	14	296	496	464	648
5	425	467	491	687	15	321	470	548	623
6	279	472	560	600	16	332	457	498	685
7	330	472	519	661	17	372	496	510	668
8	387	487	516	693	18	299	469	460	658
9	371	468	599	562	19	262	480	566	628
10	276	475	487	655	20	272	488	501	618

IV. Conclusion

This study effectively solves the problem of inefficient allocation of research resources in international business disciplines of private universities by constructing a research resource integration system under distributed computing architecture. The system adopts the dominant resource fair allocation algorithm, and the integration duration is controlled within the range of 3.107 seconds to 4.879 seconds when processing 1000 resources, and the throughput reaches 457 to 496 resources per second when processing 4000 resources, which significantly improves the resource processing capability. Compared with traditional load balancing algorithms, DRF algorithm optimizes the range of load fluctuation between virtual machines to 20% to 85%, avoiding the high load state of more than 50% in traditional algorithms, and effectively prevents the system downtime problem caused by resource exhaustion of cluster nodes.

By establishing a diversified resource acquisition mechanism combining submission, cooperation and other methods, the system builds a four-layer logical architecture covering end-users, portal sites, registration centers and resource sites, and realizes unified processing and standardized management of heterogeneous data. The DDI standard extension-based indexing system ensures the accuracy and consistency of resource descriptions, laying a solid foundation for subsequent resource retrieval and utilization. Experimental validation shows that the system exhibits excellent performance in multi-resource type scenarios, can meet the actual scientific research needs of international business disciplines in private universities, and provides an effective technical solution for improving the efficiency of scientific research resource utilization and promoting the development of disciplines.

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