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Design and Implementation of Intelligent Course Scheduling System for Deep Integration of Education and Teaching

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Abstract: *With the development of higher education and the continuous increase of the number of students, under the premise of limited classroom resources, the curriculum arrangement is more onerous. Course scheduling is one of the very important and complex management work in school teaching management. In this paper, parallel genetic algorithm is applied to solve the course scheduling problem, and a course scheduling system based on parallel genetic algorithm is designed and implemented, which can reflect the actual course scheduling situation to a large extent and achieve the optimization of multiple objectives as much as possible, so as to improve the efficiency of course scheduling.*

Keywords: *course scheduling; parallel genetic algorithm; timetable problem; computational efficiency*

1. Introduction

Timetable problem is a kind of multi constrained resource scheduling combination optimization problem, which has a wide range of applications, including train timetable, flight timetable, urban highway operation table, hospital ward scheduling table and so on. The arrangement of school curriculum is also an application of timetable problem. Curriculum scheduling problem (course scheduling problem) refers to the multi factor constrained problem of scheduling courses in a limited period of time and the number of classrooms.

Manually arranging the curriculum usually takes a lot of working days. In addition, there are often conflicts between time and place in the manually compiled curriculum. The arrangement of computer curriculum is a representative problem in the field of computer application, which has been paid attention to and has not been satisfactorily solved. In order to make the computer automatically complete the task of curriculum arrangement, many software manufacturers have made great efforts and developed the corresponding automatic course arrangement system. However, from the actual use, the practicability and universality of these systems are still not satisfactory. On the one hand, it is attributed to the fact that the course scheduling problem is a very complex system engineering, which is very difficult to be comprehensive. On the other hand, due to their own particularity, the automatic course scheduling software is difficult to be widely applicable and fully meet all requirements. Especially in the process of manual fine-tuning, a small change will cause a major adjustment of all course scheduling, which is also very difficult to solve in practical application. Therefore, it is imperative to develop a new and more practical computer intelligent course scheduling software. This paper uses genetic algorithm to solve the course scheduling problem. Its search process has self-organizing intelligence, parallelism and robustness, and the operation is simple. It can rely less on the actual situation to realize the optimization of the course schedule. It provides a better solution for the course scheduling of colleges and universities with complex constraints.

2. Related Research

In the 1990s, the research on Course Scheduling abroad is still very active. For example, the school of management of vastapur University in India.

Arabinda tripathy, Jean Aubin and Jacques a. Ferland of Montreal University in Canada, Charles fleutent et al. [1]. Arabinda tripathy's work is aimed at arranging the curriculum in units of "people". He uses Lagrange relaxation method and branch and bound technology to solve. The disadvantage of this

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method is to reduce the number of variables and artificially cause conflicts between subjects. A. Tripathy also studied the scheduling of graduate courses. He used the method of multiple course groups to deal with conflicts (that is, according to the contradiction of students' course selection, he held a large number of courses many times in a week). Jacques a. Ferland and others divided the course scheduling problem into two sub problems: schedule problem and grouping problem. In the timetable problem, a main timetable is formed according to the registration of students and the availability of teachers and classrooms. For large classes with a large number of students, a week should be divided into several time periods. The grouping problem is to assign students to each time period. The two problems are related, and the heuristic function is constructed by penalty factor. The Saphir course scheduling decision support system developed by them is divided into several modules, such as data processing, automatic optimization, interactive optimization and so on. The main method of the system to solve the contradiction is also to adopt multiple course groups, which is inseparable from the western teaching management system.

Another group of scholars also applied simulated annealing to the study of course scheduling [2-5]. Simulated annealing was first proposed by Kirkpatrick et al in 1983 [6]. It is a random optimization algorithm inspired and abstracted from the natural solid annealing process. The starting point of simulated annealing for solving optimization problems is based on the similarity between the annealing process of solid matter in physics and general optimization problems. When annealing a solid substance, it is often heated first so that its particles can move freely. Later, with the gradual decrease of temperature, the particles gradually form a low-energy lattice. If the temperature drop rate near the condensation point is slow enough, the solid material will form the ground state with the lowest energy, and there is a similar process in the optimization problem. Simulated annealing has been used to solve many optimization problems in practical application and achieved good results, but using it to solve the problem of course scheduling is still in the stage of model experiment, and there are still many problems to be solved.

Literature [7] aims at the problems existing in the course arrangement process of colleges and universities, such as error prone, time-consuming and laborious, and is committed to improving the shortcomings of the course arrangement system in Colleges and universities, and designing an automatic course arrangement system suitable for college teaching. According to the function of automatic course scheduling, literature [8] improved the traditional genetic algorithm, improved the performance and efficiency of automatic course scheduling, and designed and developed an intelligent educational administration management system. Literature [9] designed and completed the physical education curriculum arrangement system based on chaotic genetic algorithm, which is convenient for the management of physical education curriculum and the arrangement of physical education curriculum. Literature [10] designed the course scheduling algorithm of computer public laboratory by using genetic algorithm, and developed the comprehensive management system of computer public laboratory according to the needs of students of different majors for course learning resources.

Based on PC, network and other hardware resources, this paper constructs the computing platform of small PC cluster system based on Linux + PVM and windows + MPI. The objectives of multiple course scheduling problems are analyzed quantitatively, and the optimization objective space of genetic algorithm is established. Aiming at the course scheduling problem, the gene coding scheme, chromosome structure and genetic operator are designed, and the calculation method of individual fitness evaluation function and the overall optimization algorithm of course scheduling are proposed. Design and implement the parallel genetic algorithm of course scheduling system.

3. Genetic Algorithm Design of Course Scheduling System

3.1. Construct Gene Coding and Chromosome

The primary consideration in genetic algorithm is how to express its problem, that is, how to encode the actual parameters related to the solution target to make it suitable for GA operation. This is the key and difficulty of the algorithm. In classical genetic algorithms, integer coding, floating-point coding, DNA coding and binary coding methods are often used. The advantages and disadvantages of coding methods are related to the complete expression of information, the design and execution efficiency of genetic operators, and ultimately directly affect the convergence speed.

1) Hybrid gene coding

The key to the successful implementation of genetic algorithm is to construct an appropriate gene structure. Set the hybrid gene coding as the "gene" of the genetic algorithm of the system. The hybrid

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gene coding is based on the string coding to encode all parts of the gene structure into a string. The gene composition rule is: teacher number + class number + course number, and the corresponding bit width is 8 + 1 + 1, as shown in Figure 1.

Figure 1: Gene coding structure

(1) Teacher ID

Since teachers occupy the core position in the constituent elements of the timetable, and if teachers' names are used directly, there will be the problem of teachers' duplicate names. Therefore, we set a unique teacher number for each teacher with a fixed width of 8 digits. This is just the code used in setting. When printing the timetable, the system will directly convert it to the teacher's name.

(2) Class sequence number (class ID)

In order to solve the problem of "one teacher with multiple classes", a natural number is added after the teacher number to represent the teacher's teaching class number.

(3) Course ID

In order to solve the problem of "multiple courses", a natural number is added to the gene code to represent the teacher's course number. For example, 1 represents the first course taught by the teacher, 2 represents the second course taught by the teacher, and so on. In this way, the characteristics of the course can be determined through the specific identification of gene coding, and the course arrangement and effective allocation of teachers in a specific period of time can also be solved. This coding method gives appropriate settings to the conflict of the curriculum and the precautions of curriculum arrangement in the coding, and reflects all the problems to be considered in the arrangement of the curriculum from the coding. As long as the system processes the coding according to the algorithm, a perfect curriculum can be obtained.

2) Chromosome representation

As for the structure of chromosome, we adopt the representation of teachers as the main body. The relationship among teachers, classes and courses has been reflected in the gene coding structure. Then a chromosome actually represents a teacher's weekly curriculum, that is, a teacher's weekly schedule.

The two-dimensional table composed of N chromosomes is called "individual", that is, a course scheduling scheme (or a solution), which contains the relationships of all the above five entities.

3.2. Generation of Initial Population

Using data sheet course_ Plan stores an individual, and each record line is a chromosome, representing a teacher's weekly schedule. Several teachers form a "population". In the individual table, the row represents the teacher's weekly schedule, and the list shows the teacher's T1 ~ T25 time slices. For each chromosome, a random function is used to generate a number of 1 ~ 25, and the teacher's gene code is filled in. If there is data in the array variable corresponding to the generated random number, it will be regenerated until all gene codes are filled into the array without repetition. This gives you an initial timetable. According to the size of the population (the number of teachers), a certain number of initial tables are generated to form the initial population. The program uses the calculate tools class to generate the initial population.

3.3. Conflict Detection and Elimination

Genetic algorithm is an evolutionary algorithm, so its implementation needs an evolutionary basis. The initial population is generated by using a simple random method. If there is a situation that does not meet the hard constraints in the course scheduling process, there will be various conflicts in the population, but this is the starting point of genetic algorithm.

1) Conflict detection

The individuals in the population are traversed in turn, and four conflict detection functions are defined in the program: Class -

Time conflict detection function, teacher time conflict detection function, classroom time conflict

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detection function, classroom capacity -

Class number conflict detection function. The four conflicting functions indicate whether the conflict exists in the individual by detecting the return value (RESi) of their respective functions. If the return value is 0, there is no conflict. If the return value is greater than 0, there is a conflict. The return value res, shown as in formula (1) (initial value 0) defined in the overall conflict detection function is:

$$res = res + RESi + RES2 + RES3 + RES4 \quad (1)$$

Therefore, if the return value res of the overall conflict detection function is greater than 0, it indicates that there is at least one conflict in the current schedule.

2) Conflict elimination

The purpose of course scheduling genetic algorithm design is to obtain the optimal individual in the population by genetic operation on the individual in the initial population. If an individual (i.e. a course scheduling scheme) conflicts and the schedule is not feasible, then the individual fitness value will be punished at this time, so as to reduce the individual fitness value. In the process of genetic operation, the individual may be eliminated. Eliminating schedule conflict through genetic operator is an embodiment of the advantages of genetic algorithm, which highlights the characteristics of genetic algorithm "survival of the fittest and survival of the fittest".

3.4. Individual Fitness Evaluation

According to the requirements of course scheduling, the designed individual fitness evaluation function is a mechanism of punishment and reward. Specifically, if an individual does not meet the hard constraint, the algorithm will punish the individual (minus a weight). For example, we need to reduce the priority of the two teachers in the same course so that they can better adapt to the same course. At the same time, we also designed a reward mechanism. For example, teachers prefer to attend classes at a certain time. If there is such an arrangement in the solution, we will reward the individual, that is, increase the fitness value of the individual.

Based on the multi-objective analysis of course scheduling described above, the following fitness function is adopted as formula (2):

$$Fitness=Fitness\_Value–Conflict\_Penalty\_Value+Reward\_Value \quad (2)$$

Among them, fitness_ Value represents the basic fitness value, which is an initial value of the fitness function. Because it is based on the reward and punishment mode, this value is introduced to avoid the negative overall fitness value; Conflict_ Penalty_ Value refers to the conflict penalty value, including teacher time conflict, classroom time conflict and class time conflict. Its value setting has been specified in relevant classes; Reward_ Value refers to the reward value, which is mainly specified according to the teacher's time preference settings. The preference settings are like (reward 20), general (reward 15), indifferent (reward 0), dislike (reward - 15) and very dislike (reward - 20). If any of the course scheduling results just meet the preferences set by the teacher in advance, the corresponding value will be rewarded. That is, if the result is consistent with the individual who the teacher likes more items, the higher the fitness function value is. Similarly, if the result is consistent with the individual who doesn't like more items, the lower the fitness function value is. The program needs to set the default fitness value, the penalty value of class scheduling at the same time, the penalty value of teachers scheduling at the same time, the penalty value of classroom scheduling at the same time, the penalty value that the classroom cannot accommodate all students, and the specified time specially arranged for the classroom, teachers and classes.

3.5. Design of Genetic Operator

After the initial population is generated, the individual fitness function value is still at a low level. The course scheduling genetic algorithm will simulate the idea of biological iterative evolution, take the fitness function value of the timetable as the standard to judge the individual adaptability, and iterate to find the near optimal solution. The following are some key operators that must be solved by genetic algorithm for Course Scheduling:

1) Selection operator

The individuals formed in the population are sorted according to the fitness. The individuals with the largest fitness are retained to enter the next generation directly, and the other individuals decide which

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individual enters the next generation by random comparison until the population size is met. The specific implementation method is: take out two individuals at random each time for comparison, and the individuals with large fitness value enter the next generation. On the contrary, the individuals with small fitness value are eliminated. This can ensure that the best solution can be retained every time to enter the next generation, and ensure that the genetic algorithm converges to the near optimal solution with probability 1.

2) Crossover operator

Based on the population after the selection operation, we conduct cross operation. Similar to the selection operation, we also retain the optimal solution in the population and directly enter the next generation. In the specific crossover operation, we select a random number in the [0,1] interval. If the initially set crossover probability is greater than this value, we think that the current situation meets the crossover conditions, and exchange the chromosomes of the corresponding positions of the two individuals (the curriculum arrangement of a teacher).

Firstly, this paper arranges each course scheduling scheme according to the same rules, so as to ensure that the chromosome position in each scheme is corresponding. For example, the third chromosome position in individual 1 is the weekly schedule of the teacher with teacher number ID3, so the third chromosome position in other individuals is also the weekly schedule of the teacher with the same teacher number.

The cross operation is realized in two steps. For the pairing library formed by the selection operation, the first step is to pair the newly copied individuals (course scheduling scheme) randomly in pairs; The second step is to pair individuals randomly and decide whether each pair needs crossover operation according to the preset crossover probability. In the program, a random number is generated in the [0,1] interval. If the number is less than the preset crossover probability, the crossover point is randomly selected to cross breed the matched chromosome bit string to generate a new pair of bit strings. According to the special situation of course scheduling problem, after randomly setting the intersection, the classroom and time in the chromosome corresponding to the two course scheduling schemes are crossed.

It is worth mentioning that this crossover method does not disturb the elements in the gene structure, avoiding the conflict between teachers and courses. At the same time, when generating the initial population, all individuals (course scheduling scheme) are feasible course scheduling schemes, and the classroom capacity and type meet the class requirements, which also avoids the conflict between the mismatch between the classroom capacity and the class number.

3) Mutation operator

Although mutation occurs with a small probability, it ensures the diversity of the population, prevents the search solution from falling into the local suboptimal solution, and effectively suppresses the premature phenomenon of genetic algorithm.

In the process of random generation of course scheduling scheme, the random method is still used. For the population with mutation operation, the optimal individual in the population is retained and directly enters the next generation. In the mutation operation, an individual's chromosome is randomly selected and a random number is generated in the [0,1] interval. If the initially set mutation probability is greater than this value, we will randomly select a classroom from all classrooms to replace the classroom at this position of the chromosome, or randomly select a time period from all time periods to replace the time at this position of the chromosome.

3.6. Termination Conditions of Genetic Operation

In the algorithm, we design two termination conditions: first, when the genetic operation reaches the specified evolutionary algebra, we exit the genetic operation; Second, when the number of iterations is reached, check whether the optimal individual in the population does not meet the hard constraints (such as the conflict of teachers' time). If so, punish the individual and continue the iteration until the optimal individual is found and meets the hard constraints.

It is worth noting that the second condition test is not carried out until the number of iterations is reached. The second condition test is carried out only after the number of iterations is exceeded, and the test is carried out every cycle until the individual satisfying the condition is found. The flow chart of this algorithm is shown in Figure 2.

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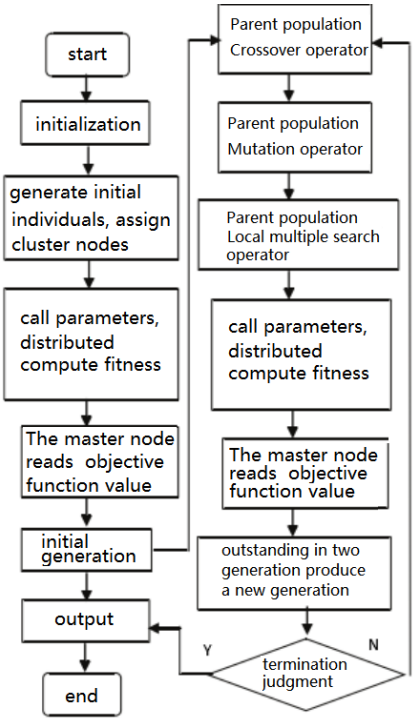

Figure 2: Program flow chart

4. Parallel System Construction

This topic uses MPI parallel library to develop the parallel program of this topic, and adopts cluster architecture to realize the establishment of parallel system. The cluster architecture system adopts standardized devices, which is relatively easy to construct and cheap, greatly reduces the threshold of high-performance computers, and accelerates the popularization and application of high-performance computers. For the education and scientific research departments with limited funds and urgent needs for parallel environment, it is technically feasible to use the existing computers to form a small or even heterogeneous cluster system. Because for most universities and research institutions, they generally have the hardware conditions to establish a small-scale network-based workstation and PC parallel cluster system without large investment, while the software can be downloaded free from the Internet.

The cluster has low requirements for hardware, which can be workstations or ordinary microcomputers. Generally, it is best to choose machines with the same structure and speed, which is easier to achieve task balance. The network adopts the commonly used Ethernet and has large communication bandwidth as much as possible. The cluster system structure is shown in Figure 3.

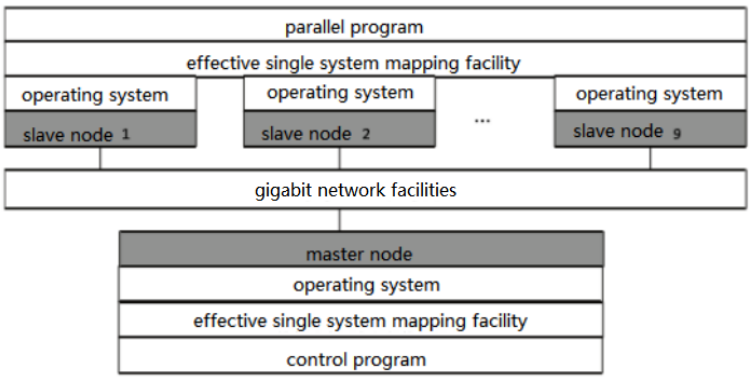

Figure 3: Cluster system structure

Parallel programming based on the principle of MPI and parallel computing of master-slave language. The improved parallel genetic algorithm runs on the cluster system. The system consists of master node and slave node.

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5. Implementation of Course Scheduling System Based on Parallel Genetic Algorithm

5.1. Establishment of Experimental Environment

In this system design, using the existing computer and network equipment resources in the laboratory, an 8-node parallel cluster system based on Linux + PVM and windows + MPI is established respectively. In order to ensure the communication bandwidth, we installed dual network cards on each node. The specific construction process is given below.

The operating system is Linux, and redhat9.0 is selected here 0 is the operating system of the node, which comes with a PVM. In addition, before installing the PVM parallel environment, the LAN should be built first, and the nodes should be able to Ping each other. Configuration of PVM system. Install PVM while installing Linux system.

5.2. Implementation of Course Scheduling System

Using the previously established 8-node parallel cluster system environment of windows + MPI, run the course scheduling system based on parallel genetic algorithm. The whole system includes user login, course scheduling data control and management, course scheduling condition control and automatic course scheduling function. Course scheduling data control management includes course information management, class information management, teacher information management, teacher site information management, overall information control of teaching time and teaching plan information management. Course scheduling condition control includes the setting of basic rules of course scheduling, pre scheduling, joint scheduling, fixed no class time between teachers and classes, etc. When the data and relevant control rules are loaded, the automatic course scheduling can be executed, the course scheduling results can be viewed, and the corresponding modifications can be made manually. Course scheduling results include total schedule query, teacher schedule query, class schedule query, classroom schedule query, etc.

1) System login

Through the database user information management, the course scheduling administrator can log in to manage the course scheduling. Teachers and students can also log in this system to query teachers' timetable and class timetable. The system login interface is shown in Figure 4. Select the user login category in the category tab.

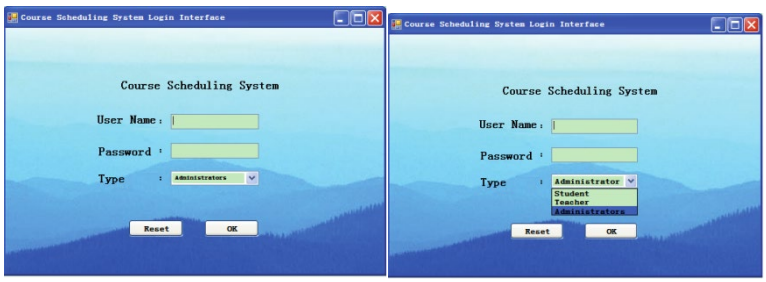

Figure 4: User login interface of course scheduling system

2) Administrator Course Scheduling Management Interface

After logging into the system, the administrator can realize the management of course scheduling information, such as data information modification, course scheduling condition control, execution of course scheduling, query of course scheduling results, etc. The interface window is shown in Figure 5.

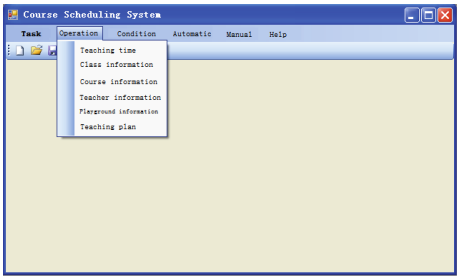

Figure 5: Course scheduling system management interface

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In the data operation tab, you can add and modify course scheduling information, including course information management, class information management, teacher information management, teacher site information management, overall information control of teaching time and teaching plan information management. For example, the teaching plan information management interface is shown in Figure 6.

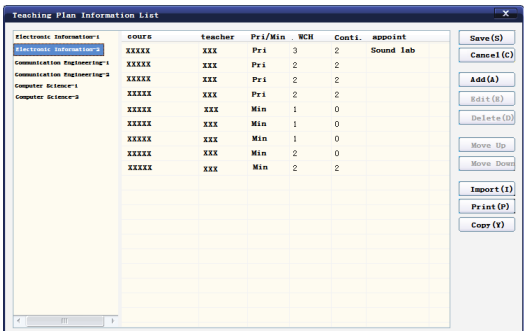

Figure 6: Teaching plan management interface

The course scheduling condition setting tab can set the basic rules of course scheduling, pre scheduling, combined class scheduling, fixed no class time between teachers and classes and other rules. When the information and rules are maintained, the course can be arranged automatically.

3) Course scheduling result query

By executing the course scheduling instruction in the automatic course scheduling phenomenon card and running the course scheduling process based on parallel genetic algorithm, we can quickly realize the course scheduling and display the results. Course scheduling results include total schedule query, teacher schedule query, class schedule query, classroom schedule query, etc. The class schedule is shown in Figure 7. The blue font is the course name and the red font is the teacher and classroom information.

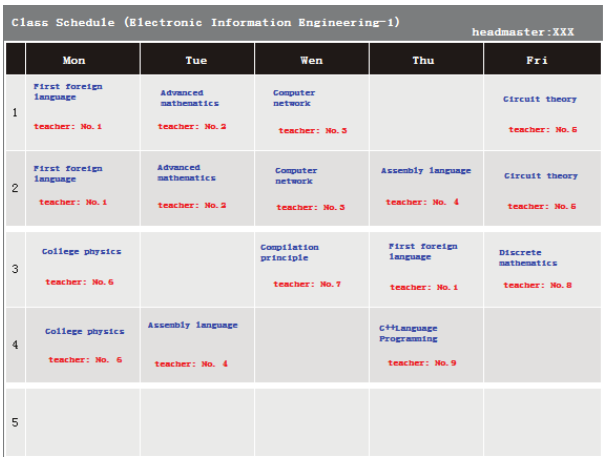

Figure 7: Class schedule query

6. Conclusion

In this paper, parallel genetic algorithm is applied to the design of course scheduling system, which greatly improves the efficiency of course scheduling. At the same time, it is found that parallel computing in cluster system has great potential, because it makes full use of the available software and hardware resources, and is a practical parallel computer system.

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