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Application and effect evaluation of intelligent computing in education and teaching reform and innovation

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ABSTRACT

A multi-objective optimisation method based on the colony ant algorithm is studied to address the problem of learning resource allocation in a high-dimensional data environment. Each ant makes its own search decisions, but their sex hormones interact to speed up the search. A training method based on multi-objective optimisation is designed. Interaction with teachers and classmates is carried out and improvements are made to their global optimisation ability through forward and backward methods. The Pareto record set saves and updates. A set of multi-objective resource scheduling algorithms is constructed. The experimental results show that all the methods proposed in this paper can achieve better results in limited projects.

KEYWORDS Learning resource planning; resource constraints; ant algorithm; multi-objective optimisation; heuristic backward improvement
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1. Introduction

The learning resource sequencing problem (RCPSP) mainly allocates resources efficiently. The RCPSP has a broad application prospect, and many practical problems can be described as the RCPSP, such as final test problems, system integration design, software development, etc. There is a termination-start order restriction between jobs in the RCPSP, where the start time of each job cannot be earlier than the end time of the job that preceded it. It is a dynamic programming method based on a time node. The RCPSP is an NP-hard problem, and its fast and efficient solution is the critical problem.

In recent years, the research on the RCPSP has been deepening, and the research on multi-objective sequencing has attracted wide attention. The method constructs the teacher-student relationship through simulation teaching to achieve the best outcome (Shi et al., 2020). The existing TLBO algorithm has been widely used in constrained and unconstrained continuous optimisation, multi-objective optimisation of heat exchangers, multi-objective economic load optimisation, etc. However, studies on the multitarget RCPSP have not been reported. This project intends to study a multi-objective learning algorithm (MOTLBO) based on TLBO theory: design efficient codec, cross operation, optimisation strategy and high dimensional multi-objective optimisation methods (Tang and Meng, 2021). The comparison of numerical simulations and algorithms verifies the proposed method.

2. Problem description

The MORCPSP sets the engineering behaviour group as $M = \{0,1,\cdots,n\}$, where jobs 0 and n are virtual activities that represent the start and end of the project. For each activity, j $\in M$,r_j represents its start time, c_j represents its duration, and Q_j represents its set of forward activities. There are T kinds of renewable resources. Activity j occupies resource unit h_{jk} of class k when run. All agreed work cannot be interrupted, and as long as the project has been started, it must be continued (Meng et al., 2020). This virtual behaviour has 0 duration and required resources. The combination of the maximum completion period (MS) and maximum capital input (RI) is called MORCPSP-MS-RI. Here is a description of the problem:

$$\min[MS, RI]\,, \tag{1}$$

$$s.t. MS = r_n\,, \tag{2}$$

$$RI = \sum_{k=1}^{T} z_k \max_{t\in[0,T]} h_k(t)\,, \tag{3}$$

$$r_i + c_i \le r_j, \forall j \in M, \forall i \in Q_j\,, \tag{4}$$

$$\sum_{j\in E(t)} h_{jk} \le \varepsilon_k, \forall k \in [1,T], \forall t \in [0,T]\,, \tag{5}$$

$h_k(t)$ is the resource k used at point t in time. ε_k is the most significant resource consumption used in the process of teaching implementation. z_k represents the money invested at a particular time and $E(t)$ represents a group of operations being performed at a particular time t. Formulas (2) and (3) determine the maximum completion time, MS, and the total resource investment, RI. Formula (4) represents the priority limit of the operation. Formula (5) represents the project's resource limitation, where r is a feasible solution for a multi-objective optimisation problem, and φ is the set of all feasible solutions. The necessary and

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sufficient conditions for two feasible scheduling solutions $r^1, r^2 \in \varphi$ are:

$$\begin{cases} MS(r^1) \le MS(r^2) \\ RI(r^1) \le RI(r^2) \end{cases}, \tag{6}$$

When the left side of the inequality is strictly less than the right side, then r^1 is said to control r^2, denoted as $r^2 \prec r^1$. If there is no $r^1 \in \varphi$ for $r^* \prec r'$, then r^* is said to be Pareto optimal. The set of Pareto optimisations is called the Pareto set. The solution of MORCPSP-MS-RI is essentially to find the optimal solution to the problem (Wang and Zuo, 2021). This method is a population evolution, and the process is divided into two parts: teacher and individual. The teacher is the best individual in the group, and the others are like students who learn from the teacher, and if the new person is better than the old one, they replace him. During the individual phase, two individuals are randomly selected for each individual, and a new individual is formed by learning from each other. If this individual performs well, the poor one is replaced. The method mainly includes the following steps.

Step 1: Initialise the population.

Step 2: Select the best person to be a teacher.

Step 3: Students learn from teachers.

Step 4: Learn from each other.

Step 5: Determine whether the end condition is met. If yes, output the optimal solution; otherwise, go to Step 2.

This project intended to study a multi-objective generalised least squares estimation method based on MORCPSP-MS-RI. Therefore, a multi-objective TLBO algorithm was explicitly designed for MORCPSP-MS-RI. The code for each individual contains a list of resources and behaviours. The behaviour list $\delta = (\delta_0, \delta_1, L, \delta_n)$ represents the priority of the behaviour, and the resource list $\varepsilon = (\varepsilon_1, \varepsilon_1, L, \varepsilon_r)$ represents the updated resource constraints (A Keivani, JR Tapamo., 2021). Active list coding performs much better than other methods. Because MORCPSP-MS-RI is an extension of the RCPSP, this paper uses the task table to sort the actions. A decoding method based on sequence generation is proposed to improve the algorithm. The jobs are arranged in the order of the job list to the earliest start time following the resource constraints specified in the resource list. The starting population of the algorithm consists of Q individuals, and the initialisation steps for each individual are as follows.

The resource input quantity $\varepsilon_k \in [\varepsilon_{k,\min}, \varepsilon_{k,\max}]$ of the class k is randomly generated. $\varepsilon_{k,\min} = \max_{j \in M} h_{jk}$ is defined by those operations k that account for the most significant project share, and $\varepsilon_{k,\max}$ is generally defined manually. A biased random sampling method is proposed based on latest completion date. The detailed steps are as follows:

Suppose that R^s is the active set selected after cycle s, and $R^1 = \{0\}$. The active set $R^s_E = \{j \in M \setminus R^s, Q_j \subseteq R^s\}$ that defines options represents an alternative event in the next period after s events are selected, and the probability μ_j of $j \in R_E$ selecting event in each period is:

$$\mu_j = \frac{\mu_j + 1}{\sum_{i \in R_E} (\mu_i + 1)}, \tag{7}$$

where $\mu_j = \max_{j \in R_E} LFT_i - LFT_j$. The above loop is executed until all activities are selected. During the semester, the teacher selects any teacher from the Pareto dataset and hybridises all the students to generate new individuals. A new individual is generated during the learning period by exchanging two subjects. According to the coding characteristics of MORCPSP-MS-RI, the following hybrid operator construction method is proposed. Two intersections are used. two different integers w_1 and w_2 ($w_1 < w_2$) are first arbitrarily generated from segment [1,n-1] thereby generating a new activation list as follows:

$$\delta^n_j = \delta^1_j, 0 \le j \le w_1, \tag{8}$$

$$\begin{aligned} &\delta^n_j = \delta^2_s, s = \min\{s \mid \delta^2_s \notin \{\delta^n_0, \cdots, \delta^n_{w1}\}\} \\ &w_1 + 1 \le j \le w_2 \end{aligned}, \tag{9}$$

$$\begin{aligned} &\delta^n_j = \delta^1_s, s = \min\{s \mid \delta^1_s \notin \{\delta^n_0, \cdots, \delta^n_{w2}\}\} \\ &w_2 + 1 \le j \le n \end{aligned}, \tag{10}$$

where $\delta^n, \delta^1, \delta^2$ represent the activity list of the new individual and the activity list of the two individuals used to cross.

$$\varepsilon^n_k = (1 - \beta)\varepsilon^1_k + \beta\varepsilon^2_k, 0 \le k \le T, \tag{11}$$

$\beta \in [0,1]$ stands for learning rate, the rate at which poorer individuals learn from better individuals. ε^n_k, ε^1_k, ε^2_k represent the resource of the new individual resource list and the resource of the k species in the resource list of the hybridisation of two individuals. During the teaching phase, the student is set as the first crossover, and during the learning period, the teacher is set as the second crossover. If one party can control the other parties, the weak party is set as the first exchange party, with the excellent party set as the second party, and otherwise the same method is adopted. If the newly generated individual cannot be replaced by the advantages of the first generation of hybridisation, then the first generation will not be replaced.

In the teaching process, each new individual generated by teachers and students will improve its local optimisation ability through forward-reverse optimisation (FBI). The maximum completion time is reduced without changing the overall capital investment. Forward-reverse optimisation sorts the jobs according to the completion order of the tasks, uses the inverse SSGS method to generate the job plan, performs hierarchical sorting according to the job's start time, and finally uses the forward SSGS algorithm to generate the job plan. This method uses the Pareto file library to solve multi-objective learning problems. The optimal solution set is obtained through the control relation in the initialisation process. Pareto data are constantly updated with new entities. I is the new individual, and the individuals in the Pareto record are represented by E_j,j = 1,2,L,|QE|. |QE| is the size of the Pareto file collection, and then it is updated as follows.

Step 1: Determine that the Pareto file collection is empty. If yes, add a solution I to the file group to terminate the upgrade. Otherwise, go to Step 2.

Step 2: Determine the appearance of j, so that C or $I =_j$ is established. If any original file group is retained, the update is terminated. Or go to step three.

Step 3: Determine the correctness of $E_j pI$ according to j = 1,2,⋯,|QE|. If this is set, E_j is removed from the Pareto file set and is added to the Pareto file set to complete the update. The multi-objective optimisation method of MORCPSP-MS-RI is presented. The method executes group evolution at two levels, teacher and student, and obtains the final set of non-inferior solutions by continuously updating the document library.

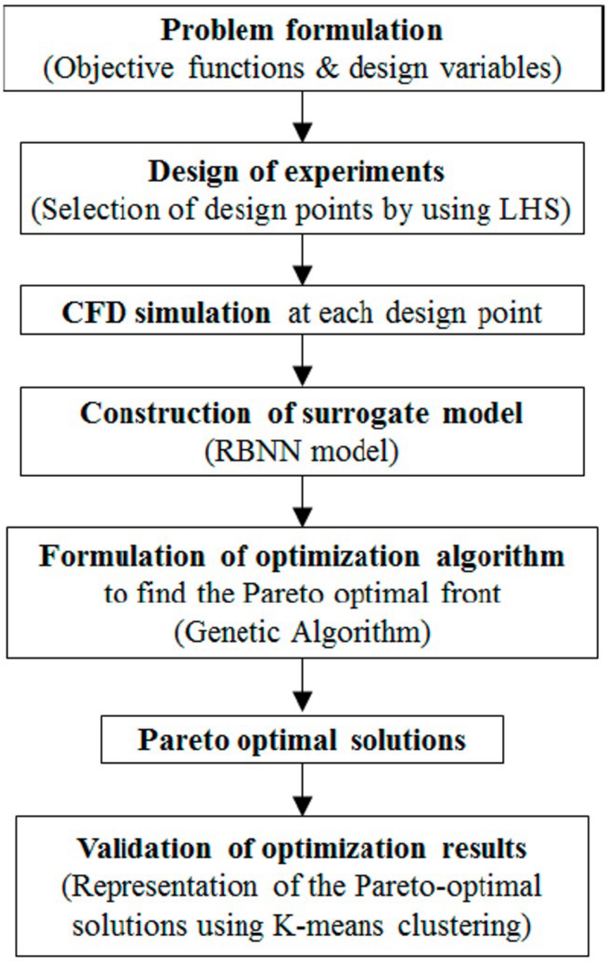

Figure 1. MOTLBO process for solving MORCPSP-MS-RI.

In terms of the complexity of the operation, the calculation amount of SSGS decoding is $O(n^2T)$ where n is the size of the project, and T is the number of renewable resources. The crossover operation is used to generate a new entity, the computation amount is $O(n)$, and the update to Pareto storage is $O(|QE|)$. The population size is analysed, and the complexity of the new population is found to be $O((n+|QE|)Q)$. It turns out that the size of |QE| is the same as the size of n, so the complexity of the problem is reduced to $O(nQ)$. The two steps of synthetic decoding and group updating show that the multitarget search algorithm has low operational complexity and can carry out multitarget searches effectively.

3. System design objectives

The teaching and management of the university includes classroom management, curriculum arrangement, laboratory management and administrative housing management at all levels. There are only dedicated management information systems in all aspects, but they cannot operate effectively because of the neglect of information sharing and integration. If there is some change, it will cause a chain reaction, resulting in many information changes and duplication. Therefore, this paper proposes to rely on the campus network and fully use the existing network equipment. It uses advanced internet technology, object-oriented databases and other methods to optimise the school's educational resources. In terms of architecture, this study establishes a set of intelligent, interactive, open and universal campus management architecture based on the web browser architecture.

3.1. Database establishment and description

Unlike the usual relational database model, the paper takes the object-oriented approach, which requires a stable core goal for some time in advance and then develops various educational materials around that goal. This paper selects a room and introduces a concept of spatial topology. Originally used to describe the interrelationships between various molecules in a material, in this system, it is used to describe the interrelationships between various rooms in a university. This kind of spatial topological relationship with the classroom as the node is relatively fixed in the campus, and it is straightforward to correspond with reality one by one. In practical applications, the eight-neighbour method is usually used to express the spatial connection between house A and the surrounding houses, and the data description of House A is shown in Figure 2. The topological calibration of a single building does not have much effect on the management of the school, but when it is combined with the educational and research work being carried out at a particular time and in a particular space, the governance structure of the overall educational resources "leaps out of the paper".

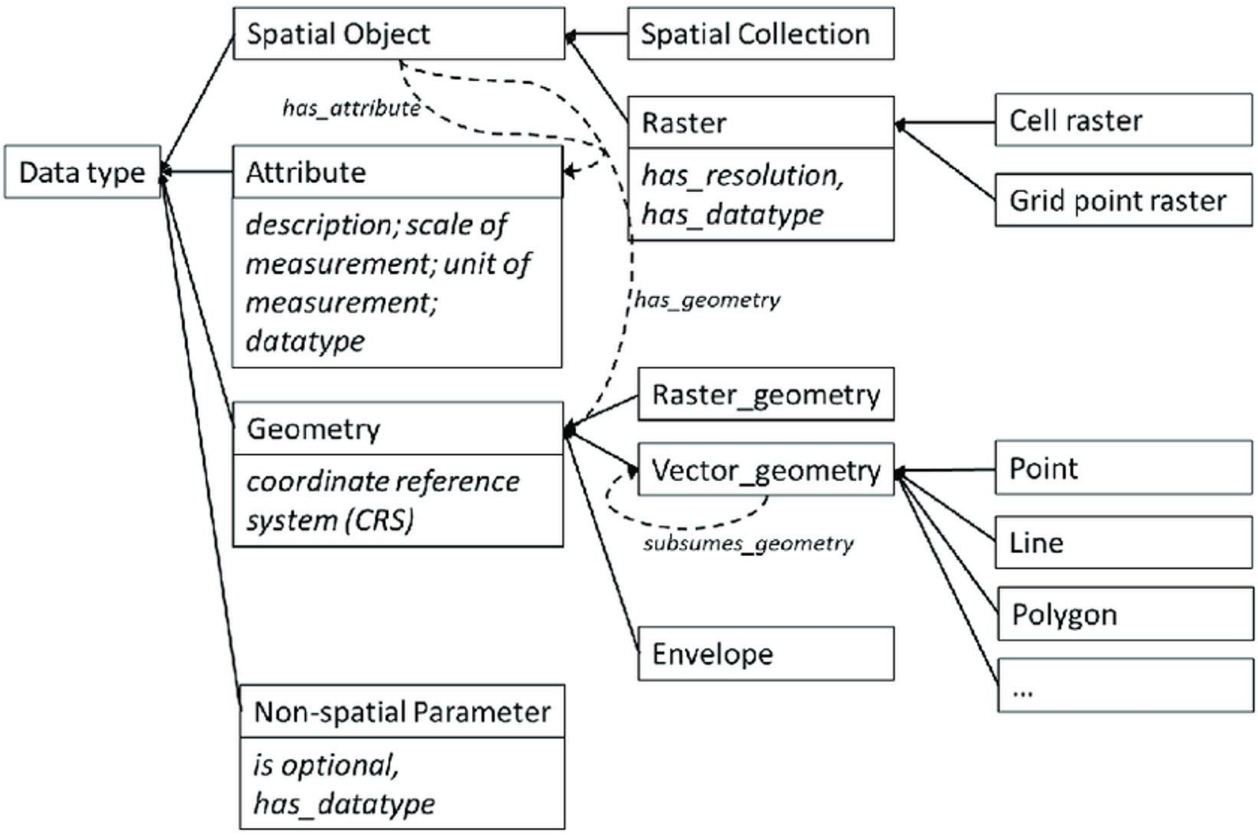

Figure 2. Spatial object data description.

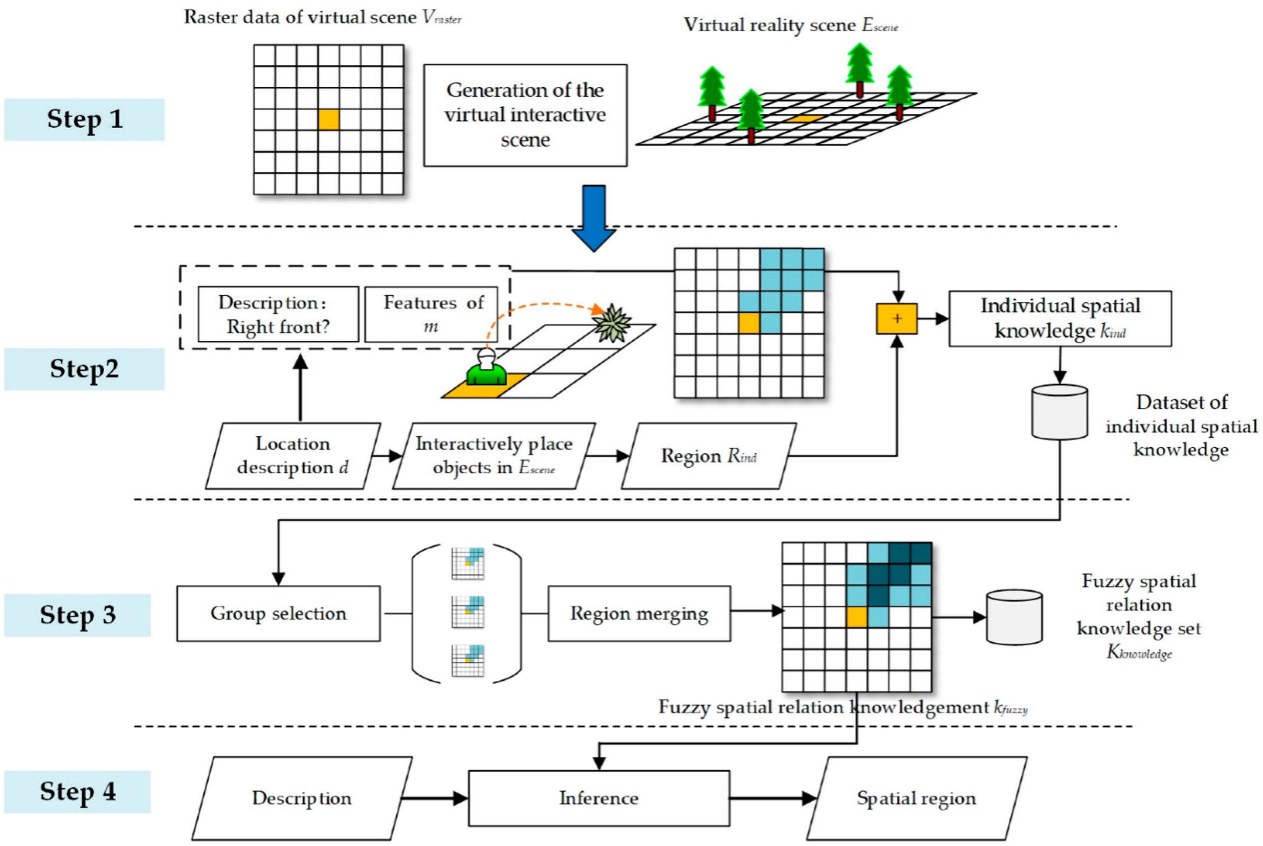

Figure 3. Data description of spatial objects.

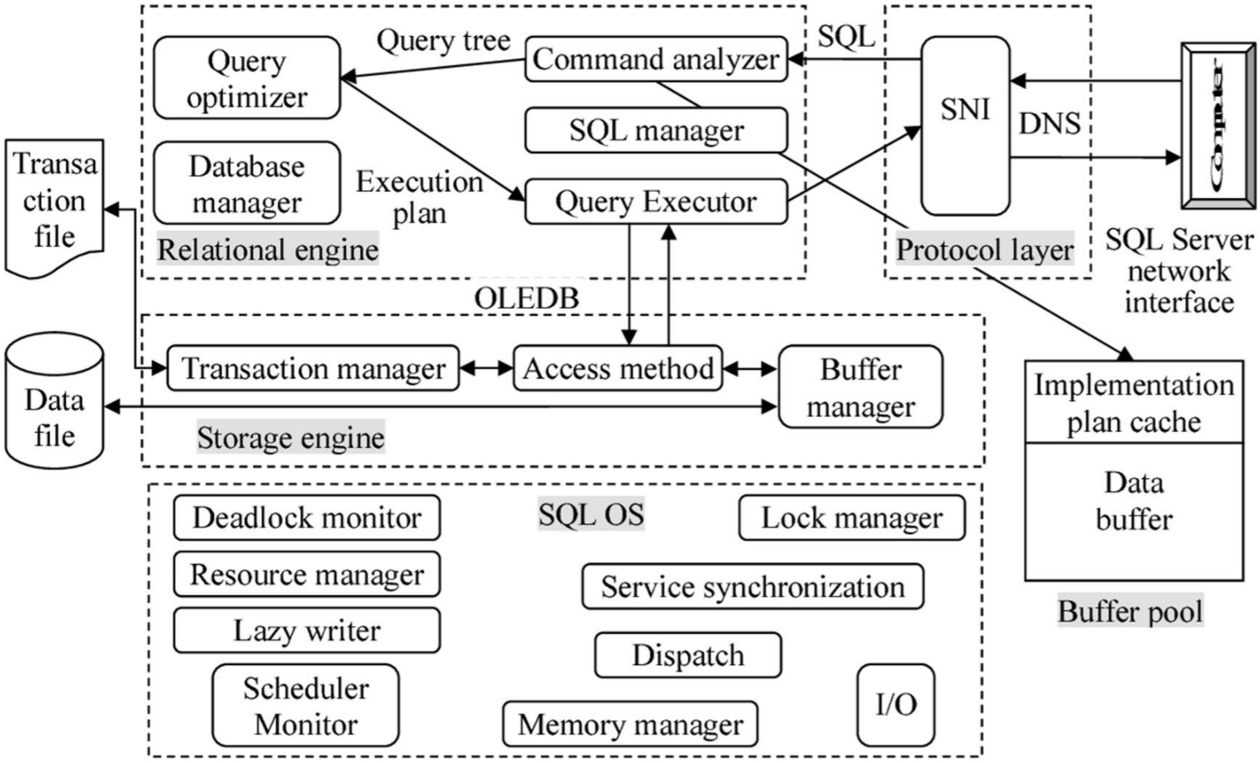

Figure 4. Architecture of the teaching resource management system.

The school introduction is similar to this building, except there is an additional route: one is the number of students, and one is the attribute. A description of room 305 in Building A is shown in Figure 3 (Xu et al., 2021). This requires modifying the traditional class schedule, divided by class; the "classroom" is only part of the unit. In this system, the curriculum arrangement is classroom-centred, and the corresponding class becomes an attribute of the classroom goal.

3.2. System architecture

The B/S three-layer structure for Web browsers is a standard and open information exchange platform. Users access dynamic or static pages with teaching information through the browser and send queries or management requests to the server through the HTTP protocol. The user's request is responded to by the Web application server running the Java program, connected to the teaching resource database through the JDBC data interface, retrieves the relevant information in the database, which is processed according to the information, and finally returned to the Web server, and then fed back to the user. The B/S structure divides the teaching resource scheduling management system into the foreground application program and the background database. The system uses MySQL as the basis of database design, and the foreground application uses JSP, Server let and JavaBeans mixed programming to achieve all the data transmission work. The system architecture is shown in Figure 4.

3.3. System function block diagram

The Campus navigation module provides an entry point for visitors to roam the campus using touch screens in each academic building. Space queries provide the ability to determine what a particular room is being used for at a particular time or what classes are being taught. The default query returns a list of available study rooms in a particular building at the current time. Custom querying allows users to generate search criteria according to their requirements.

4. Algorithm testing and analysis

There is little research on the MORCPSP, and no unified problem set has been formed. Even the evaluation of the advantages and disadvantages of this method is a problem that needs further discussion. A multi-objective RCPSP model is established.

All the problems in the Patterson problem set are selected, and the shortest construction period and the minor weighted delay are taken as the optimisation objective $\omega_n, \sum\omega_n = 1$. The Patterson problem set has been used extensively, 110 in total. It includes one to three types of renewable resources, with five questions relating to one resource and six questions relating to two resources. The remaining 99 questions relate to three types of resources. Secondly, the target value is set for each scheduling problem. The optimisation results can be easily obtained using the critical route method without resource constraints, so the CPM method determines the engineering objectives. The length of the main path provided by the path planning is taken as the target time of the project. In the path planning, the fastest completion time provided by CPM is taken as the final deadline. The tasks on the critical path are assigned random values in the range [1.0,2.0], and a random value in the range [0,1.0] is assigned as the penalty factor for lag. This paper proposes a project schedule planning method based on the CPM method, and its corresponding function value is determined as the objective function.

For the transformation of the Patterson problem library, various methods can be used to solve these problems. By calculating the difference between the optimal solution provided by the algorithm and the target value, the square sum $\sum[\omega_n(f_n\text{-}f^*_n)^2]$ of the deviation degree of each target function and the target value can be calculated. This is used as an evaluation criterion to compare the overall performance of various methods. The maximum cycle of the learning resource ranking problem is 100 times, 50 times for each of the two populations. After testing, other parameters are determined as follows:

$\alpha(1,1) = \alpha(2,2) = 1.0, \alpha(1,1) = 0, \alpha(2,1) = 0.1$

$\rho = 0.6, \rho^1 = 50, \rho_2 = 200, \rho_3 = 1000$

The single colony algorithm and several standard heuristic algorithms are selected, including the shortest duration, most extended duration, minimum time difference, maximum time difference, minimum latest end time, minimum latest start time and maximum resource utilisation. The method is applied to 110 Micropipes and compared with the minimum d_{min}, maximum d_{max} and mean d_{mean} of the objective function. The results of the test are shown in Table 1, where R_d is the proportion where the average score for each method is higher than the average score for the problem. In the distributed system based on the AMD 1.83 GHz processor studied in this paper, the solving time of the resource scheduling problem designed based on learning is less than 0.015 seconds, while the solving time of other methods is less than 0.010 seconds. Table 1 shows that the learning-based resource classification problem is the most effective. This paper will also investigate the effect of different sample sizes on the method's effectiveness. There are 48 problems with task number J = 22, 45 problems with task number J = 27, and 12 problems with task number J = 50. Figure 5 shows the effectiveness of three methods for calculating optimisation problems of varying sizes, with the mean value between the solution results of each method and the objective function as the vertical axis. The error of the single colony ant algorithm is 3.15% larger than that of the single colony ant algorithm when the computation amount is 50. The experimental results show that different colony ant optimisation methods can better deal with large-scale and complex learning resources.

Table 1. Test results of solving the efficiency of different algorithms.

Algorithm name	d_{min}	d_{max}	d_{mean}	R_d / %
Learning resource sequencing problem	54.99	57740.47	5102.09	-
Ant colony algorithm	54.99	58847.79	5138.33	0.74
Minimum and latest end-time	54.99	65615.46	5919.46	16.69
Minimum and latest start time	54.99	79979.49	6579.76	30.21
Maximum resource utilisation	54.99	86242.01	7070.09	40.18
Maximum duration	54.99	86330.48	8193.05	63.10
Minimum time difference	54.99	92867.83	9024.44	80.07
Minimum duration	54.99	84676.81	10946.17	119.31
Maximum time difference	54.99	124738.02	12063.48	142.13

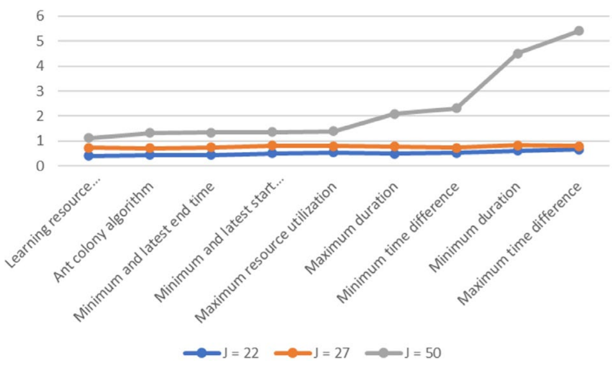

Figure 5. Influence of project size on algorithm efficiency.

5. Conclusion

This paper studies different group ant algorithms to minimise project progress and weight job delay. This paper proposes a learning resource optimisation method based on resource constraints with multiple objectives. Finally, using this system as an example, the resource allocation problem of various methods under multiple targets is compared and analysed. The experimental results show that different methods of colony ant optimisation have apparent advantages. This is evident in large, complex projects. During the experiment, it was found that all kinds of colony ant algorithms have a disadvantage: their pheromone accumulation speed is too fast, and it is easy to fall into local precocious optimal solutions. This limits the application of many swarm ant algorithms in the optimisation process. The future development trend is solving these problems by utilising regulatory control mechanisms and designing a new optimal algorithm.

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References

[1] Keivani A and Tapamo JR (2021). Task scheduling algorithms in cloud computing: A review. Turkish Journal of Computer and Mathematics Education (TURCOMAT). 12(4), pp1041-1053.

[2] Shi C, Ding L, Wang F, Salous S and Zhou J (2020). Joint target assignment and resource optimization framework for multitarget tracking in phased array radar network. *IEEE Systems Journal*. 15(3), pp.4379-4390.

[3] Tang L and Meng Y (2021). Data analytics and optimization for smart industry. *Frontiers of Engineering Management*. 8(2), pp.157-171.

[4] Meng S, Huang W, Yin X, Khosravi MR, Li Q, Wan S and Qi L(2020). Security-aware dynamic scheduling for real-time optimization in cloud-based industrial applications. *IEEE Transactions on Industrial Informatics*. 17(6), pp.4219-4228.

[5] Wang Y and Zuo X (2021). An effective cloud workflow scheduling approach combining PSO and idle time slot-aware rules. *IEEE/CAA journal of automatica sinica*. 8(5), pp.1079-1094.

[6] Xu J, Pan X, Zhao J and Fu H (2021). Virtual Reality-Based Fuzzy Spatial Relation Knowledge Extraction Method for Observer-Centered Vague Location Descriptions. *ISPRS International Journal of Geo-Information*. 10(12), pp. 833.