ISSN: 2414-1895 DOI: 10.6919/ICJE.202008_6(8).0032

Design of Course Scheduling System Based on Particle Swarm Optimization Algorithm

Li Wang, Zhuwen Tang, Wei Wang

Department of Electronic Engineering, Xi'an Aeronautical University, Xi'an Shaanxi 710077, China

Abstract

Reasonable and efficient course scheduling system is essential to improve the efficiency of university teaching management. The course scheduling problem is a combination optimization problem. It needs to allocate time and classrooms reasonably, meet specific constraints and avoid conflicts. In this paper, by analyzing the various factors and constraints involved in the course scheduling problem, a mathematical model of the course scheduling problem is constructed, and the realization process and steps of the course scheduling system design based on particle swarm optimization are given. Based on MATLAB software for simulation design and testing, the results of automatic scheduling are given from the three perspectives of class, teacher, and classroom. The results show that the designed scheduling system can meet the constraint relationship between teachers, classrooms, and courses, and can improve utilization of low-level classrooms.

Keywords

Course Scheduling System; Constraints; Mathematical Model; Particle Swarm Optimization Algorithm; Simulation Results.

1. Introduction

The purpose of course scheduling system is to ensure that the classes arranged by the school can reasonably allocate time, space and teachers to systematically plan and organize the entire teaching order [1][2]. Faced with the traditional manual scheduling of energy-consuming and inefficient, the intelligent and high efficiency of the scheduling system makes it become crucial in the construction of campus teaching affairs, and the demand is becoming more and more obvious. At present, many scientific researchers and the teaching affairs departments of universities have developed some course scheduling systems [3]-[5] using computer technology, but these course scheduling systems have simple functions, poor flexibility, and high software development costs. Therefore, designing a practical, automated, and efficient course scheduling system is the only way to improve teaching management.

The scheduling problem is to optimize the combination of the five major factors such as class, time, course, classroom, and teacher. It is a non-deterministic problem of polynomial complexity. This paper builds a mathematical model based on the influencing factors and constraints involved in the course scheduling problem, and uses particle swarm optimization (PSO) to optimize the solution. It describes the particle encoding and implementation process in detail, and collects the actual course task information to obtain the class, teacher, classroom schedules, and the results verified the effectiveness and feasibility of the designed schedule system.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202008_6(8).0032

2. Mathematical Model

This section describes the process of constructing a mathematical model for scheduling problems. By analyzing the five basic factors of class, classroom, teacher, time, and curriculum, the hard and soft constraints and mathematical representations that the scheduling system needs to meet are summarized. Mathematical model of the course scheduling system is constructed.

2.1 Constraints of the Course Scheduling System

The scheduling problem belongs to the category of timetable problems. Its essence is a fully combinatorial optimization problem with multiple constraints, combined planning and multi-objective seeking optimal solutions. Curriculum arrangement mainly involves five elements: class, classroom, teacher, time, course, etc. The process of solving the scheduling problem is to construct conditional functions for these five elements [6][7], maximize the effective use of resources, and compile a feasible scheduling system.

Class: Class is a collection of students. Each class has a specific number, and in the course of arranging the course, the class is the main core of the scheduling problem. Each class can only take one course within a specific time slot.

Classroom: The classroom is the place where teaching is implemented. In order to improve the utilization of teaching resources, the number of students in the class should be more suitable for the classroom capacity. In the design process, the courses should be arranged on the lower floors as much as possible, which can reduce the time for changing classrooms between classes.

Teachers: Teacher numbers, names, and teaching subjects are important factors that need to be considered in the course scheduling system. A teacher can teach one or more courses, but only one course can be taught at the same time.

Time: Time is an important factor in the course scheduling process. In the design process, try to distribute the class time evenly to avoid being concentrated in a certain time slot or too free in a certain day.

Courses: Courses are the midpoint between teachers and students. Each course has its own name, category and other attributes, and different courses have different teachers.

In the course scheduling, the constraints can be divided into hard constraints and soft constraints according to the above factors. Hard constraints refer to the most basic necessary conditions, that is, the necessary conditions that classes, teachers, and classrooms cannot violate under the premise of time. Soft constraints refer to optimization conditions, which are based on hard constraints to achieve better results. According to the five factors involved in the course scheduling problem, this article divides the five factors into three hard constraints and two soft constraints. Detailed description is seen from Table 1. The three hard constraints will ensure the accurate operation of the timetable and avoid conflicts, while the two soft constraints will improve the rationality of the timetable on the basis of achieving the necessary conditions.

Table 1. Constraints of course scheduling system.

Hard constraints	
①	In the same time slot, there can only be one classroom
②	In the same time slot, one teacher can only teach one class
③	In the same time slot, one class can only take one course
Soft constraints	
④	Try to distribute the courses evenly
⑤	Try to increase utilization of lower floors

ISSN: 2414-1895 DOI: 10.6919/ICJE.202008_6(8).0032

2.2 Mathematical Model of Course scheduling System

It can be seen that, the course scheduling problem is an optimization problem, and the course can be arranged more rationally on the basis of satisfying the constraints, so that the optimal solution can be obtained. In the course scheduling, we mainly achieve two goals [7]: (1) fully meet the hard constraints involved in the course scheduling, these conditions are the most basic and can not be violated, otherwise the schedule will not be feasible . (2) As far as possible to meet the soft constraints involved in the course arrangement, these conditions will improve the quality of the schedule and make the course arrangement more reasonable, scientific and practical.

According to the hard constraint condition ①, we define the matrix as follows:

$$\boldsymbol{M}=\begin{pmatrix} \boldsymbol{m}_{11} & \cdots & \boldsymbol{m}_{1n} \\ \vdots & \ddots & \vdots \\ \boldsymbol{m}_{m1} & \cdots & \boldsymbol{m}_{mn} \end{pmatrix}_{m\times n} \tag{1}$$

Where, $\boldsymbol{m}$ indicates the number of classrooms and $\boldsymbol{n}$ is the number of time slices. One week can be divided into 20 time slices, and the time slice division is shown in Table 2. By filling the course tasks into the matrix, the hard constraint condition ① is met.

Table 2. Time slice division.

Monday	Tuesday	Wednesday	Thursday	Friday
T1	T5	T9	T13	T17
T2	T6	T10	T14	T18
T3	T7	T11	T15	T19
T4	T8	T12	T16	T20

According to the hard constraint condition ②, the objective function $\boldsymbol{f}_1$ is constructed:

(1) The vector of the number of classes scheduled for each time slice of the teacher $\boldsymbol{i}$ is defined as $\boldsymbol{CT}^{(i)}$:

$$\boldsymbol{CT}^{(i)}=\left(\boldsymbol{c}_1,\cdots,\boldsymbol{c}_n\right)^T \tag{2}$$

Where, $\boldsymbol{i}$ is the teacher number, $\boldsymbol{c}_j$ indicates the schedule arrangement on the time slice $\boldsymbol{j}$.

(2) We can judge whether the teacher $\boldsymbol{i}$ violates the constraint ②, and define the 0-1 vector that violates the constraint ②:

$$\boldsymbol{CTN}^{(i)}=\left(\boldsymbol{cn}_1,\cdots,\boldsymbol{cn}_n\right)^T \tag{3}$$

$$\boldsymbol{cn}_j=\begin{cases} 1,\boldsymbol{c}_j>1,\boldsymbol{c}_j\in\boldsymbol{CT}^{(i)} \\ 0,\boldsymbol{c}_j\le 1,\boldsymbol{c}_j\in\boldsymbol{CT}^{(i)} \end{cases} \tag{4}$$

(3) We can construct $\boldsymbol{f}_1$, which represents the violation severity of constraint ②:

$$\boldsymbol{f}_1=\sum_{i=1}^{k_1}\left[\boldsymbol{CTN}^{(i)}\right]^T\boldsymbol{CT}^{(i)} \tag{5}$$

Where, $\boldsymbol{k}_1$ represents the number of teachers.

According to the hard constraint condition ③, the objective function $\boldsymbol{f}_2$ is constructed:

ISSN: 2414-1895 DOI: 10.6919/ICJE.202008_6(8).0032

(1) The number of classes scheduled for each time slice of the class i is defined as $CC^{(i)}$:

$$CC^{(i)}=\left(c_1,\cdots,c_n\right)^T \tag{6}$$

Where, c_j indicates the schedule arrangement on the time slice j.

(2) We can judge whether the class i violates the constraint ③, and define the 0-1 vector that violates the constraint ③:

$$CCN^{(i)}=\left(cn_1,\cdots,cn_n\right)^T \tag{7}$$

$$cn_j=\begin{cases}1,c_j>1,c_j\in CC^{(i)}\\0,c_j\le 1,c_j\in CC^{(i)}\end{cases} \tag{8}$$

(3) We can construct f_2, which represents the violation severity of constraint ③:

$$f_2=\sum_{i=1}^{k_2}\left[CCN^{(i)}\right]^T CC^{(i)} \tag{9}$$

Where, k_2 represents the number of classes.

According to the soft constraint condition ④, the time slices corresponding to the schedule of the schedule system should be evenly distributed within a week. The definition matrix M_{rest} represents the distribution of the schedule in each classroom and each time slice:

$$M_{rest}=\begin{pmatrix}m_{11} & \cdots & m_{1n}\\ \vdots & \ddots & \vdots\\ m_{m1} & \cdots & m_{mn}\end{pmatrix}_{m\times n} \tag{10}$$

According to the soft constraint condition ⑤, the course scheduling system should increase the utilization rate of lower-floor classrooms, so a weighted approach is adopted to assign larger weights to classrooms with high utilization rates. To satisfy the soft constraints ④ and ⑤, we construct the objective function f_3 as:

$$f_3=\sum_{i=1}^{m}\theta_i g\left(M_{rest}\right) \tag{11}$$

Where, $g\left(M_{rest}\right)$ represents the sum of the rows of matrix M_{rest}.

In order to improve the rationality of the course scheduling system, this paper comprehensively considers all hard constraints and soft constraints, and the overall objective function of the course scheduling system is:

$$argminF = w_1 f_1 + w_2 f_2 + w_3 f_3 \tag{12}$$

3. Course Scheduling System Design Based on Particle Swarm Optimization

3.1 Mathematical Description of Particle Swarm Optimization

We set the particle size m of the population P, to be denoted as $P=\{p_1,p_2,p_3,\cdots,p_m\}$. Each particle is described by its position and speed. In the search space of the D dimensional vector, the position of the particle p_i can be expressed as $x_i=(x_{i1},x_{i2},x_{i3},\cdots,x_{iD})$, and the corresponding velocity can be expressed as: $v_i=(v_{i1},v_{i2},v_{i3},\cdots,v_{iD})$. The individual extreme value of the particle p_i is expressed as p_{best_i}, and the group extreme value of the particle p_i is expressed as g_i.

The update formula of particles is described as [8][9]:

ISSN: 2414-1895 DOI: 10.6919/ICJE.202008_6(8).0032

$$\begin{cases} v_i \leftarrow v_i + c_1 rand(\ )\left(p_{best_i} - x_i\right) + c_2 rand(\ )(g_i - x_i), \\ x_i = x_i + v_i, \end{cases} \tag{13}$$

Where, c_1 and c_2 are the learning factors, $rand(\ )$ is a function of random variables that follow a uniform distribution on [0,1], v_i expresses the updated particle velocity, and x_i is the updated particle position.

3.2 Implementation Process of Course scheduling system designed by PSO

The particles of this model adopt the method of segmented coding of floating point numbers, and uniformly encode the data of each row of teaching classes, hours, teachers and so on. If there are a total of 10 opening tasks in the opening task book, the value range of each particle is [0,10], and the value of particles is i, which means the opening task i.

The flow chart of using PSO for course scheduling system is shown in Figure 1, the specific steps are:

(1) Set the parameters of the PSO and initialize the population randomly;

(2) Use the fitness function, equation (12), to evaluate the particles and find individual extreme values and group extreme values;

(3) Use equation (13) to update the position and velocity of particles;

(4) Determine whether to terminate the iterative operation. If the maximum number of iterations is reached, terminate the iteration, and output contemporary optimal particles as the result of the course arrangement; otherwise, continue the iteration.

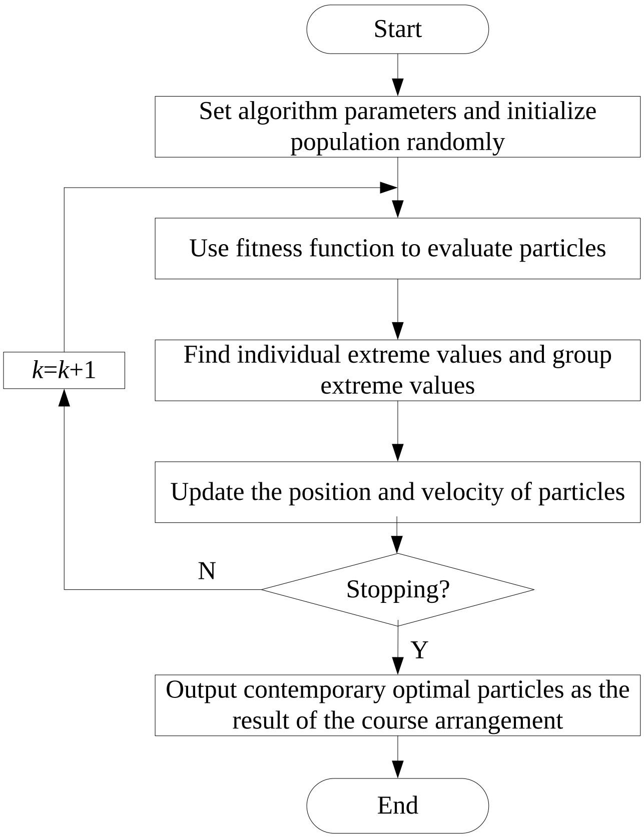

Figure 1. Flow chart of course scheduling system based on PSO.

4. Experimental Results and Analysis

4.1 Parameter Settings

The course start task book is shown in Table 3. As can be seen from Table 3, there are a total of 8 classes that need to take 5 courses, and 5 teachers have to take classes. The larger the population of

ISSN: 2414-1895 DOI: 10.6919/ICJE.202008_6(8).0032

particles, the more beneficial it is to improve the search space of the solution and avoid the generation of local optimal solutions [10]. However, the larger the value, the longer the calculation time, so we set the the number of particles is m =50. We set the maximum flying speed of the particle as v_{max} =0.5, to avoid the problem that the flying speed of the particle is too fast and fly away from the optimal solution. Set the inertia weight w =0.5, so that the particles have better memory. Set learning factors $c_1 = c_2$ =1, so that particles can jump out of the local optimal solution. The initialization of particles is linear random initialization, so that each particle falls evenly in the search space of the solution.

Table 3. Course start task book.

Number	Classes	Students	Course	Teacher
1	2	40	Advanced Mathematics	Teacher Wang
2	5	40	College English	Teacher Li
3	6	40	College Physics	Teacher Zhou
4	7	40	Engineering Drawing	Teacher Liu
5	8	40	Linear Algebra	Teacher Zhang
6	5	40	Advanced Mathematics	Teacher Wang
7	6	40	College English	Teacher Li
8	7	40	College Physics	Teacher Zhou
9	8	40	Engineering Drawing	Teacher Liu
10	2	40	Linear Algebra	Teacher Zhang

4.2 Results Anaylsis

4.2.1 Class schedule

From the perspective of the class, the schedule arrangement of each class fully complies with the hard constraints; there is no conflict in the distribution of time. After adding the constraint ④⑤, the scheduling of each class is evenly distributed within a week, which is conducive that the students should arrange their work and rest properly and make better use of their spare time. The schedule of Class 2 and Class 5 are shown in Table 4 and Table 5.

Table 4. The schedule of Class 2

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1 (8:30-9:15) (9:25-10:10)		Advanced Mathematics (Teacher Zhang) Classroom 2-1			College English (Teacher Liu) Classroom1-1
Session 2 (10:30-11:15) (11:25-12:10)	College English (Teacher Liu) Classroom 2-1		Linear Algebra (Teacher Zhou) Classroom 1-3		Engineering Drawing (Teacher Wang) Classroom 2-2
Session 3 (14:00-14:45) (14:55-15:40)	Linear Algebra (Teacher Zhou) Classroom 1-1	Engineering Drawing (Teacher Wang) Classroom 1-3		Advanced Mathematics (Teacher Zhang) Classroom 1-2	
Session 4 (16:00-16:45) (16:55-17:40)					

ISSN: 2414-1895 DOI: 10.6919/ICJE.202008_6(8).0032

Table 5. The schedule of Class 5

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1 (8:30-9:15) (9:25-10:10)		College Physics (Teacher Li) Classroom 1-3	Engineering Drawing (Teacher Wang) Classroom 1-1		
Session 2 (10:30-11:15) (11:25-12:10)		Linear Algebra (Teacher Zhou) Classroom 1-3	College English (Teacher Liu) Classroom 1-1	Linear Algebra (Teacher Zhou) Classroom 1-2	
Session 3 (14:00-14:45) (14:55-15:40)	College English (Teacher Liu) Classroom 1-3	Advanced Mathematics (Teacher Zhang) Classroom 1-2			
Session 4 (16:00-16:45) (16:55-17:40)			Advanced Mathematics (Teacher Zhang) Classroom 1-1		

Table 6. Teacher Wang’s schedule.

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1 (8:30-9:15) (9:25-10:10)			Engineering Drawing (Class 5) Classroom 1-1		
Session 2 (10:30-11:15) (11:25-12:10)			Engineering Drawing (Class 6) Classroom 1-2		Engineering Drawing (Class 2) Classroom 2-2
Session 3 (14:00-14:45) (14:55-15:40)		Engineering Drawing (Class 2) Classroom 1-3	Engineering Drawing (Class 8) Classroom 2-1		
Session 4 (16:00-16:45) (16:55-17:40)		Engineering Drawing (Class 7) Classroom 1-1			

Table 7. Teacher Li’s schedule.

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1 (8:30-9:15) (9:25-10:10)	College Physics (Class 7) Classroom 1-2	College Physics (Class 5) Classroom 1-3			
Session 2 (10:30-11:15) (11:25-12:10)	College Physics (Class 6) Classroom 2-3	College Physics (Class 8) Classroom 2-1		College Physics (Class 6) Classroom 2-1	College Physics (Class 8) Classroom 2-3
Session 3 (14:00-14:45) (14:55-15:40)				College Physics (Class 7) Classroom 2-1	
Session 4 (16:00-16:45) (16:55-17:40)					

4.2.2 Teacher schedule

It can be seen from the schedules assigned by each teacher that each teacher’s course also fully meets our hard constraints. From the point of view of time and classroom allocation, there is no conflict in scheduling, and the time of scheduling is evenly distributed, which is helpful for teachers to better

ISSN: 2414-1895 DOI: 10.6919/ICJE.202008_6(8).0032

arrange the content of the class. Teacher Wang and Teacher Li's schedule are shown in Table 6 and Table 7.

4.2.3 Classroom Schedule

We got the schedule of each classroom according to the total schedule. The schedules of the first-level classrooms 1-1, 1-2 and 1-3 are shown in Table 8, Table 9 and Table 10 respectively; the schedules of the second-level classrooms 2-1, 2-2 and 2-3 are shown in Table 11, Table 12 and Table 13, respectively.

From the classroom schedule, we can see that the total number of classroom schedules on the first-level classroom is 27 lessons in a week, and the total number of classroom schedules on the second-level classroom is 13 lessons. In other words, the number of classroom schedules on the lower floor is much higher than that of higher floor, which confirmed that the schedules meets the requirements of high utilization rate of our lower-level classrooms. It can be seen from the table that the schedule of the classrooms on the first and second floors is evenly distributed within a week.

Table 8. Classroom 1-1's schedule.

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1 (8:30-9:15) (9:25-10:10)	College English (Teacher Liu) Class 6		Engineering Drawing (Teacher Wang) Class 7		College English (Teacher Liu) Class 2
Session 2 (10:30-11:15) (11:25-12:10)	Advanced Mathematics (Teacher Zhang) Class 7	Advanced Mathematics (Teacher Zhang) Class 6	College English (Teacher Liu) Class 7		
Session 3 (14:00-14:45) (14:55-15:40)	Linear Algebra (Teacher Zhou) Class 2	Linear Algebra (Teacher Zhou) Class 7	College English (Teacher Liu) Class 7	College English (Teacher Liu) Class 7	College English (Teacher Liu) Class 7
Session 4 (16:00-16:45) (16:55-17:40)		Engineering Drawing (Teacher Wang) Class7	Advanced Mathematics (Teacher Zhang) Class5		

Table 9. Classroom 1-2's schedule.

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1 (8:30-9:15) (9:25-10:10)	College Physics (Teacher Li) Class 7				
Session 2 (10:30-11:15) (11:25-12:10)	Linear Algebra (Teacher Zhou) Class 8		Engineering Drawing (Teacher Wang) Class 6	Linear Algebra (Teacher Zhou) Class 5	College English (Teacher Liu) Class 7
Session 3 (14:00-14:45) (14:55-15:40)	Advanced Mathematics (Teacher Zhang) Class 8	Advanced Mathematics (Teacher Zhang) Class 5		Advanced Mathematics (Teacher Zhang) Class 2	
Session 4 (16:00-16:45) (16:55-17:40)					

ISSN: 2414-1895
DOI: 10.6919/ICJE.202008_6(8).0032

Table 10. Classroom 1-3's schedule.

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1 (8:30-9:15) (9:25-10:10)		College Physics (Teacher Li) Class 5			
Session 2 (10:30-11:15) (11:25-12:10)		Linear Algebra (Teacher Zhou) Class 5	Linear Algebra (Teacher Zhou) Class 2	Advanced Mathematics (Teacher Zhang) Class 8	
Session 3 (14:00-14:45) (14:55-15:40)	College English (Teacher Liu) Class 5	Engineering Drawing (Teacher Wang) Class 2			
Session 4 (16:00-16:45) (16:55-17:40)					

Table 11. Classroom 2-1's schedule.

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1 (8:30-9:15) (9:25-10:10)		Advanced Mathematics (Teacher Zhang) Class 2	College English (Teacher Liu) Class 8		
Session 2 (10:30-11:15) (11:25-12:10)	College English (Teacher Liu) Class 2	College Physics (Teacher Li) Class 8		College Physics (Teacher Li) Class 6	
Session 3 (14:00-14:45) (14:55-15:40)			Engineering Drawing (Teacher Wang) Class 8	Engineering Drawing (Teacher Wang) Class 7	
Session 4 (16:00-16:45) (16:55-17:40)					

Table 12. Classroom 2-2's schedule.

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1 (8:30-9:15) (9:25-10:10)					Advanced Mathematics (Teacher Zhang) Class 6
Session 2 (10:30-11:15) (11:25-12:10)					Engineering Drawing (Teacher Wang) Class 2
Session 3 (14:00-14:45) (14:55-15:40)			Linear Algebra (Teacher Zhou) Class 6		
Session 4 (16:00-16:45) (16:55-17:40)					

ISSN: 2414-1895
DOI: 10.6919/ICJE.202008_6(8).0032

Table 13. Classroom 2-3's schedule.

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1 (8:30-9:15) (9:25-10:10)				Advanced Mathematics (Teacher Zhang) Class 7	
Session 2 (10:30-11:15) (11:25-12:10)	College Physics (Teacher Li) Class 6				College Physics (Teacher Li) Class 8
Session 3 (14:00-14:45) (14:55-15:40)					
Session 4 (16:00-16:45) (16:55-17:40)					

In summary, we aimed at a small-scale start-up task scheduling problem, designed particle coding, and optimized the generation of class schedules, teacher schedules, and classroom schedules. The experimental results demonstrate that the optimization of the course scheduling through particle swarm optimization can effectively avoid the conflict of course scheduling, and arrange the time reasonably, which provides convenience for student learning and teacher lesson preparation, and can improve the utilization rate of the classroom.

5. Conclusion

This paper constructs the mathematical model of the course scheduling system, utilizing the hard constraints and soft constraints. Particle swarm algorithm is used to design the scheduling system, the course task information is encoded with particles, and the design process is described. Combined with specific design requirements, schedules for classes, teachers, and classrooms are given. The design results show that the scheduling results meet the constraints and can increase the utilization rate of lower-level classrooms, which fully proves the feasibility of the designed scheduling system.

Acknowledgments

This work was supported by the National Natural Science Foundation of China (grant number 61901350); Science Research Fund of Xi'an Aeronautics University (grant number 2019KY0208).

References

[1] Luo Yiqiang, Chen Zhibin. Optimization of college curriculum scheduling based on improved particle swarm optimization algorithm [J]. Computer Applications and Software, 2018, 035(006): 241-247, 303

[2] Pang Shujie, Liu Qicheng, Mou Chunxiao. Research on scheduling optimization algorithm based on inter-course association rules [J]. Computer Application Research, 2019, 36(10): 2934-2937+2942.

[3] Kingston J H. Repairing High School Timetables with Polymorphic Ejection Chains [J]. Annals of Opeations Research, 2016, 239(1): 119-134.

[4] Zheng Aiyuan, Lin Feng. Research on Selection of Course Arrangement System Based on Intuitionistic Fuzzy Decision Algorithm [J]. Journal of Chongqing University of Science and Technology (Natural Science Edition), 2017, 03: 95-98+109.

[5] Han Shu. Design and Implementation of MVC-based Experiment Course Arrangement System [D]. Beijing: Beijing University of Technology, 2016.

[6] Li Xin. Design and Implementation of Teaching Management System of Chongqing Electronic Engineering Vocational College [D]. Chengdu: University of Electronic Science and Technology of China, 2016.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202008_6(8).0032

[7] Li Jianping. Design and implementation of automated course scheduling system [J]. Automation and Instrumentation, 2015(09): 134-136.

[8] Marie-Sainte S L. A New Hybrid Particle Swarm Optimization Algorithm for Real-World University Examination Timetabling Problem [C]. 2017 Computing Conference, 2017, 119: 157-163.

[9] Jain N K , Nangia U , Jain J . A Review of Particle Swarm Optimization [J]. Journal of the Institution of Engineers, 2018, 99(4): 407-411.

[10] Li Weiming. Research on the scheduling of secondary vocational schools based on particle swarm optimization [J]. SME Management and Technology, 2015(22): 176-177.