Design of Course Scheduling System Based on Genetic Algorithm

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Abstract

Designing a reasonable automatic course scheduling system is an important way to realize the intellectualization of educational affairs, which can improve the efficiency of educational affairs and save manpower costs. Based on the analysis of the basic elements and rules of the course scheduling system, this paper builds a mathematical model of the course scheduling problem, including its constraints and objective functions. The genetic algorithm is used to optimize and solve, the chromosome coding method and implementation process are given, and the feasible course scheduling results are given in combination with the actual course tasks.

Keywords

Course scheduling system; Constraints; Objective function; Coding; Implementation process.

1. Introduction

With the continuous development of information technology, colleges and universities continue to develop in the direction of informatization, systematization, and intelligence. In the past, the school curriculum was manually operated by the teaching staff, which was inefficient and consumed a lot of manpower and material resources. Therefore, many colleges and universities have gradually switched from manual operations to APP and web operations. For example, online learning system, educational management system, Class management system, etc. [1], can improve work efficiency to a certain extent. However, the shortcomings of these systems, such as single functions, instability, and inability to automatically schedule courses, have reduced the overall performance of the system. Therefore, it is of great significance to design an automatic course scheduling system using intelligent optimization algorithms.

The course scheduling problem is a study on teachers, Classes, and course assignments. When the data size is small, linear programming, direct heuristic methods, graph theory, decision information system integration network optimization and other algorithms are used to solve [2][3] . When the data size is large, the intelligent optimization algorithm [4][5][6] is mainly used for solving. For example, Wu Songhui and Zou Haizhen [7][8], etc., decomposed the time to plan, and proposed the scheduling problem based on genetic algorithm (GA).

In this paper, based on the analysis of the basic elements and rules of the scheduling problem, a mathematical model of the scheduling problem is constructed, including constraints and objective functions. Genetic algorithm is used to optimize the solution, and reasonable schedule results are given by carring experiments on the actual scheduling task.

2. Mathematical Model

This section analyzes and studies the main characteristics of the scheduling problem, describes the basic characteristics of the scheduling problem, analyzes the basic elements of the scheduling problem. Mathematically describes these factors, sets the objective function, and builds a mathematical model of the scheduling problem.

2.1 Basic Elements and Constraints of Course Scheduling

In the course scheduling system, it is the fundamental goal to arrange teachers, students, courses, time, Classrooms, etc. reasonably, and arrange courses through their own independent constraints, so as to

obtain a reasonable teaching plan in time and space. The course scheduling problem is a multi-objective optimization problem with multiple constraints. In the course scheduling system design process, how to meet the constraints is the key to solving the course scheduling problem.

2.1.1 Basic elements

Teacher: A course will have a fixed teacher to teach, but if there are too many Classes, multiple teachers will teach at the same time.

Course: Different courses have different requirements for teachers and teaching resources. We need to choose a Classroom or a teacher according to the characteristics of the course.

Class: Class refers to the total number of students who are in Class at the same time, and is the core element of the scheduling problem.

Classroom: According to the number of students in the Class and the characteristics of the course, different types of Classrooms are allocated.

Time: Time is a very important scheduling factor. It needs to be determined according to the semester and week. Make sure that different students are given different courses in different time periods, and there can be no conflict in time.

The mathematical model variables of the course scheduling problem are described as [9]:

Class collection: $C=\{c_1,c_2,\cdots,c_n\}$;

Course collection: $K=\{k_1^e,k_2^e,\cdots,k_l^e \mid e\in\{1,2\}\}$;

Teacher collection: $T=\{t_1,t_2,\cdots,t_k\}$;

Time collection: $D=\{d_1^g,d_2^g,\cdots,d_m^g \mid g\in\{1,2,3,4,5\}\}$;

Classroom collection: $R=\{r_1,r_2,\cdots,r_p\}$.

2.1.2 Constraints for scheduling

(a) The same Class c_n can only arrange the same course k_l at the same time d_m, in the Classroom r_p taught by the teacher t_h:

$$\sum_{l=1}^{L}\sum_{h=1}^{H}\sum_{p=1}^{P}c_n d_m k_l t_h r_p \le 1 \tag{1}$$

Where, L is the number of courses, H is the number of teachers, and P is the number of Classrooms.

(b) The same teacher t_h can only arrange the same course k_l at the same time d_m, and teach Class c_n in the Classroom r_p:

$$\sum_{l=1}^{L}\sum_{n=1}^{N}\sum_{p=1}^{P}c_n d_m k_l t_h r_p \le 1 \tag{2}$$

Where, N is the number of Classes.

(c) The same Classroom r_p can only arrange the same course k_l at the same time d_m, and the teaching Class is c_n:

$$\sum_{l=1}^{L}\sum_{n=1}^{N}\sum_{h=1}^{H}c_n d_m k_l t_h r_p \le 1 \tag{3}$$

(d) The Classroom capacity r_{num} must be greater than the Class size c_{num}, ie:

$$r_{num} \ge c_{num} \tag{4}$$

(e) The school hours of the course should meet the teacher's planning hours;

(f) Classes in the same course require intervals to facilitate students' digestion and consolidation;

(g) Reasonably choose the time and space conducive to Class and avoid conflicts.

Among these constraints, conditions (a), (b), (c), and (d) are called hard constraints, while (e), (f), and (g) are called soft constraints. Satisfying the hard constraint condition means that a feasible solution is obtained, and satisfying the soft constraint condition means that the course arrangement is more reasonable.

2.2 Mathematical Model for Scheduling

2.2.1 Schedule objectives

Combined with the above analysis, the designed course scheduling system needs to integrate and reasonably allocate resources, so as to maximize resource utilization without conflicts. The objectives of designing a course scheduling system are as follows:

(1) The designed curriculum needs to meet all the hard constraints, so that all objects participating in the entire teaching activity can integrate resources within a limited time and space, so that the teaching activity can proceed smoothly.

(2) On the basis of satisfying the hard constraints, the schedule design needs to satisfy as many soft constraints as possible, so that the curriculum can be more reasonable and meet the teaching planning and learning habits of teachers and students.

In order to obtain a reasonable and feasible curriculum, we should design a reasonable objective function. During the entire course arrangement, hard constraints must be met to ensure effective results, and as many soft constraints as possible should be met. Therefore, based on the principle of fitness function, this paper combines the soft constraint conditions to design fitness function, and takes fitness function as the evaluation index of the designed course scheduling system.

2.2.2 Objective function

A reasonable interval between courses is conducive to students to learn a solid knowledge of the course, and also to help teachers prepare lessons, avoiding teachers fatigue due to intensive lesson preparation. Reasonable Classroom spacing can help students and teachers save energy, have time to rest and devote to the course review and preview the next Class. Therefore, we define course intervals and Classroom intervals to meet soft constraints and improve teaching quality.

(a) Course interval

Class hours are defined as working days, that is, five days from Monday to Friday. The time period of the Class can be divided into: the first time $d_{m_1}^{g_1}$, the second time $d_{m_2}^{g_2}$, for example, $g_1 = 1$, $m_1 = 2$ is defined as the second section period on Monday, the reasonableness of the course setting is o, described as:

$$f_1 = \frac{1}{n}\sum_{i=1}^{n} o_i \tag{5}$$

$$o = \frac{1}{1+\sqrt{\frac{1}{L}\sum_{j=1}^{L}\left(\delta_j - \bar{\delta}\right)^2}} \tag{6}$$

$$\delta = \frac{u_1\left|g_2 - g_1\right| + u_2\left|m_2 - m_1\right| - \delta_{fit}}{\delta_{fit}} \tag{7}$$

$$\bar{\delta} = \frac{1}{L}\sum_{i=1}^{L}\delta_i \tag{8}$$

Where, f_1 represents the reasonableness of the course setting, o_i represents the rationality of arranging the course of the i th Class, $\bar{\delta}$ represents the average reasonableness, and δ represents the

evaluation value of the time interval, δ_{fit} represents the ideal evaluation value, u_1 and u_2 are the corresponding weights.

(b) Classroom interval

Classroom interval is defined as:

$$f_2 = \frac{1}{n}\sum_{i=1}^{n} z_i \tag{9}$$

$$z = \frac{1}{1+\sum_{i=1}^{L-1} a_{i,i+1}} \tag{10}$$

Where, f_2 is the rationality for setting the Classroom interval, z_i is the rationality for the i th Classroom, $a_{i,i+1}$ is the evaluation value for the adjacent courses, β_1 and β_2 are the weighting values, b_1^i and b_1^{i+1} are the Classrooms for course i and $i+1$.

According to the course interval and Classroom interval, the objective function of the course scheduling system is constructed as:

$$\max(F) = \sum_{i=1}^{2} \omega_i \times f_i \tag{11}$$

Where, ω_i represents the weight corresponding to the evaluation value of the objective function f_i, i=1, 2.

3. Optimal Solution Based on Genetic Algorithm

3.1 Genetic Algorithm

Genetic Algorithm is a system algorithm according to the genetic laws of biology. The core and foundation of genetic algorithm is selection, mutation and crossover. Selection refers to the process of selecting individuals with strong survivability from old populations, generating new individuals, and forming new populations. Individuals with a high fitness value can get more breeding opportunities than individuals with a low fitness value, thereby producing more offspring. Crossover refers to the random exchange and enrichment of genes between parents in a group to create new individuals and ensure that these new gene combinations are inherited. Variation means that in a group, in order to expand the search function, the value of one or more genes on the parent chromosome changes.

3.2 Implementation Process

The standard genetic algorithm has its own calculation principles and standards, such as individuals, populations, genetic factors, etc. If it is applied to the scheduling problem, it is necessary to combine the core influencing factors of course scheduling problem with genetic algorithm. The specific implementation process is:

(1) Clarify the goal of the course scheduling problem and construct the corresponding mathematical model.

(2) Coding the core elements of the scheduling problem, such as teachers, courses, etc., and using the objective function to evaluate.

(3) Construct the genetic factors for Class scheduling, including selectin, mutation and cross chromosomes.

(4) Through the evolution process, the optimal individual is obtained.

(5) Decode the best individual, restore it to a feasible curriculum.

3.2.1 Gene coding

Different coding methods result in different schedules. The optimized coding method will make the schedule more reasonable and effective. This paper uses decimal to encode Classes, courses, teachers, time, and Classrooms.

The gene coding diagram is shown in Figure 1. Taking the timetable as an individual form, the Class, course, teacher, time, and Classroom are used as the coding information chromosome. The coding form uses the Class number—course number—teacher number—time number—Classroom number. For example: the code is 0113—0301—0202—1135—1204, which means Class number is 0113, course number is 0301, teacher number is 0202, time number is 1135, and Classroom number is 1204.

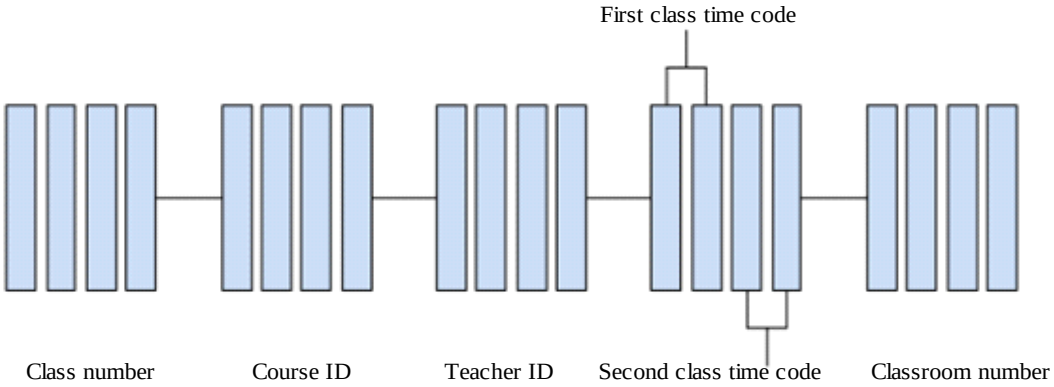

Fig. 1 Gene coding diagram

3.2.2 Genetic operator

(1) Select operator

The roulette method is used for gene selection [10]. According to the fitness values of different individuals, all individual fitness values are accumulated together to form a logical roulette wheel. The greater the proportion of individual fitness values in the total fitness value, the greater the probability of selection passed to the next generation.

Firstly, the sum of the fitness of all individuals in the current generation population is recorded as S :

$$S = \sum_{i=1}^{N} eval(x_i^{(0)}) \tag{12}$$

Where, N is the number of individuals in the population.

Secondly, calculate the probability p_i that each individual is selected:

$$p_i = \frac{eval(x_i^{(0)})}{S}, i = 1,2, \dots, N \tag{13}$$

Then, calculate the cumulative probability q_i of each individual:

$$q_i = \sum_{j=1}^{i} p_j,\ i = 1,2,\dots,N \tag{14}$$

Finally, rotating the roulette wheel randomly to select N individuals, and this process can be achieved with a uniform random function. The individual selected for each turn of the wheel is $Select_j^{(k)}$:

$$Select_j^{(k)} = \{x_j^{(k)} | R(i) <= q_{j+1} \text{ and } R(i)_{>q_j}\}, j = 1,2, \dots, N \tag{15}$$

Where, $R(i)$ represents the uniform random function of the i-th rotation.

(2) Crossover operator

For the selection of cross individuals, we adopt the method of random probability [11].

Firstly, set the cross probability P_c which is used to select cross individuals. The cross individuals selected in the kth generation are recorded as:

$$Cx_j^{(k)} = \{x_i^{(k)} | R(i) > P_c\} \tag{16}$$

Then, $Cx^{(k)}$ is pair-by-pair performed as described above to obtain the kth generation hybridized individuals.

(3) Mutation operator

Set the mutation probability P_m, perform mutation by uniform random function to generate random numbers:

$$x_{ij}^{(k)} = \begin{cases} M(x_{ij}^{(k)}), & R(i) > P_m \\ x_{ij}^{(k)}, & R(i) < P_m \end{cases} \tag{17}$$

Where, $M(x)$ is the mutation operation of the selected mutant individual.

The mutation process of $M(x)$ is: perform uniform random number operation on each chromosome of individual x. If it is greater than P_m, then mutate one bit of the binary code, that is, 0 becomes 1, or 1 becomes 0.

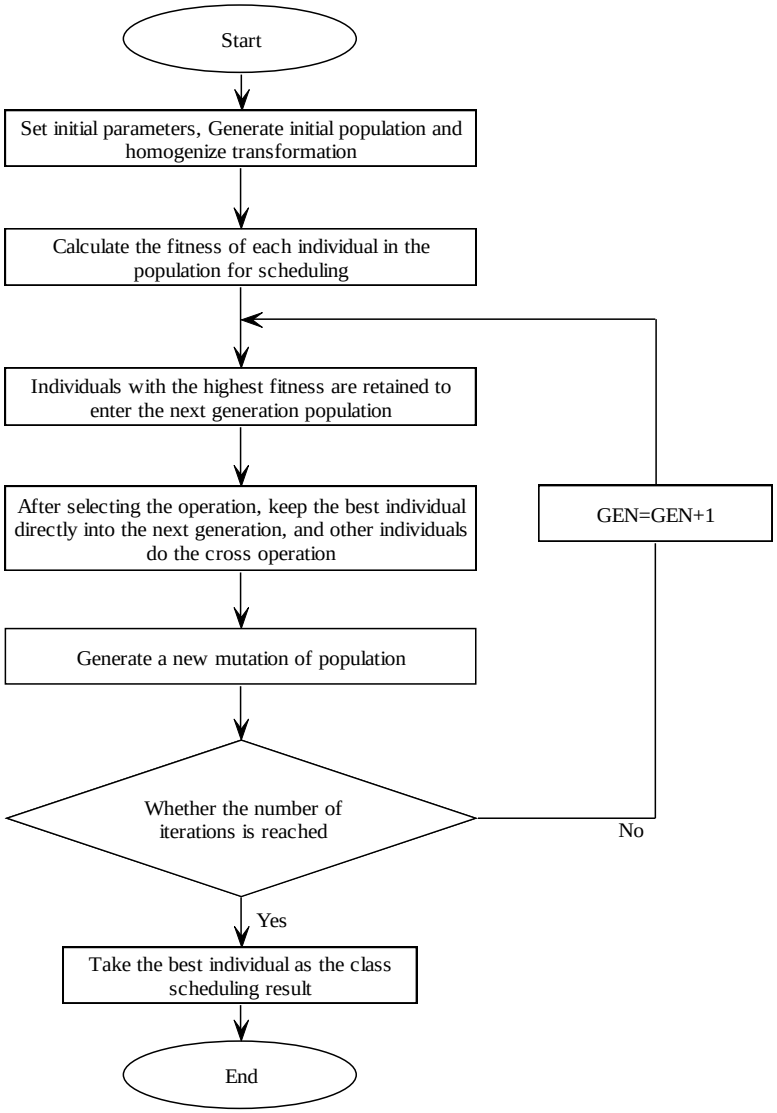

Fig. 2 The flow chart of curriculum design using genetic algorithm

3.2.3 Solution process

The flow chart of the Class scheduling system design using genetic algorithm is shown in Figure 2. The steps are summarized as follows:

(1) Set initial parameters and generate initial population;

(2) According to formula (11), evaluate each gene to find the fitness;

(3) Use the formula (15) to select chromosomes;

(4) Adopt formula (16) to carry out cross operation on chromosomes;

(5) Adopt formula (17) to mutate chromosomes to retain dominant individuals and enter the next generation;

(6) Determine whether to stop the iteration. If the maximum evolutionary algebra is reached, stop the iteration and output the best individual; otherwise continue the iteration;

(7) Decode the best individual to obtain a reasonable curriculum

4. Experimental Results and Analysis

4.1 Parameter Settings

The genetic algorithm is used to optimize the scheduling problem. Assume that the curriculum information, Classroom information, teacher information, and Class information are:

Course information: Advanced Mathematics, College English, College Physics, Circuits, College Chinese, and Electrical Engineering.

Class information: Class A-1, Class A-2 and Class A-3.

Teacher information: Teacher Wu, Teacher Li, Teacher Wang, Teacher Pan, Teacher Zheng, Teacher Gao.

Classroom information: Classroom 01, Classroom 02, Classroom 03.

The parameters in GA are set according to experience: population size is 50, crossover probability is 0.5, mutation probability is 0.01, and the maximum number of iterations is 100.

4.2 Result analysis

4.2.1 Class schedule

From the perspective of the class, the timetable obtained by genetic optimization does not violate the set constraints, the same class only arranges one course at the same time period. Meanwhile, the class of the same course is not too tight, reflecting the setting of course interval, which meets the needs of students' course learning and knowledge consolidation. Class A-1, Class A-2 and Class A-3 are listed in Table 1, Table 2 and Table 3.

Table 1 Class A-1 schedule

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1	Electrical Engineering Teacher Zheng Classroom 02	College Chinese Teacher Wu Classroom 03	Electrical Engineering Teacher Zheng Classroom 02	College Chinese Teacher Wu Classroom 02	Circuits Teacher Gao Classroom 01
Session 2		College Physics Teacher Pan Classroom 02	Advanced Mathematics Teacher Li Classroom 03	College English Teacher Wang Classroom 02	
Session 3	Advanced Mathematics Teacher Li Classroom 03	College English Teacher Wang Classroom 01	Circuits Teacher Gao Classroom 01	College Physics Teacher Pan Classroom 03	
Session 4					

Table 2 Class A-2schedule

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1	Circuits Teacher Gao Classroom 01	College Physics Teacher Pan Classroom 02	Circuits Teacher Gao Classroom 03	College Physics Teacher Pan Classroom 03	
Session 2	Advanced Mathematics Teacher Li Classroom 03	College English Teacher Wang Classroom 03	Electrical Engineering Teacher Zheng Classroom 01	College Chinese Teacher Wu Classroom 03	
Session 3	Electrical Engineering Teacher Zheng Classroom 01	College Chinese Teacher Wu Classroom 02	Advanced Mathematics Teacher Li Classroom 03	College English Teacher Wang Classroom 02	
Session 4					

Table 3 Class A-3schedule

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1	Advanced Mathematics Teacher Li Classroom 03	College English Teacher Wang Classroom 01		College English Teacher Wang Classroom 01	
Session 2	Electrical Engineering Teacher Zheng Classroom 01	College Chinese Teacher Wu Classroom 01	Circuits Teacher Gao Classroom 02	College Physics Teacher Pan Classroom 01	Circuits Teacher Gao Classroom 03
Session 3		College Physics Teacher Pan Classroom 03	Electrical Engineering Teacher Zheng Classroom 02	College Chinese Teacher Wu Classroom 01	
Session 4			Advanced Mathematics Teacher Li Classroom 02		

4.2.2 Teacher schedule

From the perspective of the teacher, the result of the course arrangement does not violate the set constraints. The same teacher only arranges one course at the same time period, and meets the setting of the course interval in the objective function. The class time is not too compact, which is conducive to teachers to prepare lessons, preventing teachers from fatigue due to intensive lesson preparation, thus ensuring the quality of teaching. The curriculum of Teacher Wu and Teacher Li is shown in Table 3 and Table 4.

Table 4 Teacher Wu schedule

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1		College Chinese Class A-1 Classroom 03		College Chinese Class A-1 Classroom 02	
Session 2		College Chinese Class A-3 Classroom 02		College Chinese Class A-2 Classroom 03	
Session 3		College Chinese Class A-2 Classroom 01		College Chinese Class A-3 Classroom 01	
Session 4					

Table 5 Teacher Li schedule

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1	Advanced Mathematics Class A-3 Classroom 03				
Session 2	Advanced Mathematics Class A-2 Classroom 03		Advanced Mathematics Class A-1 Classroom 03		
Session 3	Advanced Mathematics Class A-1 Classroom 03		Advanced Mathematics Class A-2 Classroom 03		
Session 4			Advanced Mathematics Class A-3 Classroom 02		

4.2.3 Classroom schedule

From the perspective of the classroom, the scheduling results did not violate the set constraints. Only one course was arranged in the same classroom at the same time period. The classroom arrangement reflects the role of classroom interval in the objective function, so that students have enough time for rest and preview. The schedules of Classroom 01, Classroom 02 and Classroom 03 are shown in Table 6, Table 7 and Table 8.

Table 6 Classroom 01 schedule

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1	Circuits Class A-2 Teacher Gao	College English Class A-3 Teacher Wang		College English Class A-3 Teacher Wang	Circuits Class A-1 Teacher Gao
Session 2	Electrical Engineering Class A-3 Teacher Zheng	College Chinese Class A-3 Teacher Wu	Electrical Engineering Class A-2 Teacher Zheng	College Physics Class A-3 Teacher Pan	
Session 3	Electrical Engineering Class A-2 Teacher Zheng	College English Class A-1 Teacher Wang	Circuits Class A-1 Teacher Gao	College Chinese Class A-3 Teacher Wu	
Session 4					

Table 7 Classroom 02 schedule

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1	Electrical Engineering Class A-1 Teacher Zheng	College Physics Class A-2 Teacher Pan	Electrical Engineering Class A-1 Teacher Zheng	College Chinese Class A-1 Teacher Wu	
Session 2		College Physics Class A-1 Teacher Pan	Circuits Class A-3 Teacher Gao	College English Class A-1 Teacher Wang	
Session 3		College Chinese Class A-2 Teacher Wu	Electrical Engineering Class A-3 Teacher Zheng	College English Class A-2 Teacher Wang	
Session 4			Advanced Mathematics Class A-3 Teacher Li		

Table 8 Classroom 03 schedule

Session/Week	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1	Advanced Mathematics Class A-3 Teacher Li	College Chinese Class A-1 Teacher Wu	Circuits Class A-2 Teacher Gao	College Physics Class A-2 Teacher Pan	
Session 2		College English Class A-2 Teacher Wang	Advanced Mathematics Class A-1 Teacher Li	College Chinese Class A-2 Teacher Wu	Circuits Class A-3 Teacher Gao
Session 3	Advanced Mathematics Class A-1 Teacher Li	College Physics Class A-3 Teacher Pan	Advanced Mathematics Class A-2 Teacher Li	College Physics Class A-1 Teacher Pan	
Session 4					

The experimental results give the curriculum of the class, teacher, and classroom. From the results, the curriculum of the class, teacher, and classroom all meet the hard constraints, and the curriculum can work. At the same time, the course interval between students and teachers is one day, which meets the soft constraint conditions to ensure the quality of students' learning and teachers' teaching. The classrooms of the students' and the teachers' are not far apart, which can meet the classroom interval in the soft constraints, save the energy of teachers and students, and indirectly guarantee the quality of teaching.

5. Conclusion

Based on the basic elements and constraints of the course scheduling problem, this paper establishes the objective function of the course scheduling system design, and uses genetic algorithm to optimize the solution. The genetic coding process of course task information is given, and the selection, crossover and mutation operators are designed to obtain best individuals. Combined with the specific course task information, the schedules of classes, teachers and classrooms are given. The experimental results meet the hard and soft constraints, ensuring the quality of teaching and fully prove the feasibility of the designed course scheduling system.

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