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Students test sequence arrangement optimization model

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ABSTRACT

This article is based on the problems and using the process arrangement problems in production planning algorithm, on the basis of according to the characteristics of the students physical fitness test, determined to solve the problem of two stage method: the first stage, the simplified model into a packing problem, and thus get the minimum time period, according to the time optimization principles of equilibrium, the total number of physical tests the class assigned to each time period; The second stage, in order to simplify the computation, students in as little as possible waiting time and as the objective function, simplify the problem into process arrangement problem model, the rationality of the model of different schemes to make a good evaluation, strong adaptability, have certain application promotion value.

KEYWORDS

Physical tests;
Mathematical model;
The approximate algorithm.

INTRODUCTION

At present in China, the school was a fitness test methods to understand the students' physical condition. Test including height and weight, standing long jump, vital capacity, grip, and five steps experiment, by electronic instrument automatic measurement, record and save the information. We assume that the existing school three height and weight measurement instruments, standing long jump, lung capacity measuring instruments each 1, grip strength and bench test measuring instruments each 2 sets. Height and weight, standing long jump, vital capacity, grip strength, four projects each instrument each student's average test (including the transformation of students), respectively, 20 seconds, 20 seconds, 10 seconds for 15 seconds, each instrument bench test a test 5 students, need 3 minutes and 30 seconds. Each student test to enter personal information before every project, i.e. student number, the average takes 5 seconds. To ensure that the students simply input a student number connected situation. School to arrange a day of the test time is 8:00-12:10 and 13:30 - separate two periods. The five tests are in small places to accommodate 150 students; test project has no fixed order. To participate in physical fitness test in the number of each class are shown in TABLE 1. Under the condition of the entire test period at least, to minimize the waiting time of students. And put forward related Suggestions to school after fitness test.

PROBLEM ANALYSIS AND SYMBOLIC DESCRIPTION

Problem analysis

This problem requires all students in the same class

TABLE 1 : The number of each class participate in physical fitness

Class Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Total Number	41	45	44	44	26	44	42	20	20	38	37	25	45	45	45
Class Number	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Total Number	44	20	30	39	35	38	38	28	25	30	36	20	24	32	33
Class Number	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Total Number	41	33	51	39	20	20	44	37	38	39	42	40	37	50	50
Class Number	46	47	48	49	50	51	52	53	54	55	56				
Total Number	42	43	41	42	45	42	19	39	75	17	17				

must be in the same period of time to finish the entire test project, and in the entire test under the condition of the time period required for at least, to minimize the waiting time of students. To this end, we all take part in physical fitness test section of each class, idealize conditions as far as possible, in class, the only class with class calculates the weight record time. Class as the increase of the number of, then, can be used to complete the test of time should be reduced. So we in the relationship as a constraint condition, to arrange the same time the class, we give it to the computer to complete this process, see appendix for the specific procedures. The same period of time after class arranged the arrangement of the test sequence for the same period class. Depending on each instrument is the instrument division of different priority, first consider the priority of the arrangement of the instrument, considering the test process in the back of the students have to wait until the previous classmates, in the back of the class to wait at the front of the class, so at the time of waiting for these students can arrange them to other tests. The shortest waiting times formula can be calculated out, and then arrange personnel to complete the test class accordingly.

Symbol description

ts : The beginning of the period of time;
te : The end of the period of time;
tc : Each test needs time;
r : Each instrument the number of each test;
s : The number of test machine;
tw : Each test project minimizes wait time: Class number*5;
t : Period of time equal to te-ts (s);
w : The average class size is equal to [2036/56];
n : Class number;
$bend_{i,j}$: The end time of classes i at the j instrument;
$bst_{i,j}$: The beginning time of classes i at the j instrument;
$mark_{i,j}$: i student measuring at j instrument;
C1: Height and weight test 1 instrument Numbers;
C2: Height and weight test 2 instrument Numbers;
C3: Height and weight test 3 instrument Numbers;
C4: The standing long jump test instrument Numbers;
C5: Vital capacity test instrument Numbers;
C6: Grip strength test 1 instrument Numbers;
C7: Grip strength test 2 instrument Numbers;
C8: Step test 1 instrument Numbers;
C9: Step test 2 instrument Numbers.

MODEL ASSUMPTION

Basic assumptions:

(1) After all the test done by the students can leave the scene, no need to wait for all students in the class to finish;
(2) No abnormal situation: the students to be late doing not participate in phenomenon, students arrange strictly abide by the disciplines of time as planned;
(3) in the test, all the machine working properly;

Other assumptions:

(1) When doing the test in a class for the whole, according to the student number sequence test, does not allow the class or other class cut in line.
(2) After the first done by the students, you can arrange the students (according to the first hypoth-

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esis is actually the whole class) to test on other instruments.

(3) After all the test done by the students can leave the scene, no need to wait for all students in the class to finish.

THE ESTABLISHMENT OF THE MODEL AND THE SOLUTION

The whole idea of solving the problem

This is actually a plan scheduling problems, needs to solve the following problems:

(1) Identify with the least amount of time to complete the students' entire physical fitness test, the minimum number of periods;

(2) The class (56) reasonable arrangement known to each time period;

(3) In a period of time, the condition of known fitness class, reasonable arrangement of each class's and grade's test to make the students waiting for the shortest possible time.

According to the above problems, we identify two phases to solve the train of thought:

First stage: to find the minimum time period, and the each class according to the principle of optimization model of distribution to each time period.

Time and the time period in the second stage: to known to arrange classes, build to solve the model, the waiting time of student's as little as possible operational class fitness test on a table.

The first stage of basic model and conclusion

Basic model can be simplified as: the first phase of the known start time and end time of each time period, each instrument to test the average test time and entry is not even the student information conversion time, strives for the minimum time period number and the class schedule of each time period.

Conclusion 1 time arrangement, the number of up to 710 in the morning and afternoon time arrangement, the number of up to 550 people

Conclusion 1 argument: according to each physical test project and its number of instruments and equipment, we get the following TABLE 2:

TABLE 2 : The number of testing students in test project of full load work each period

Project	Height and Weight	Standing long jump	Vital capacity	Grip	Step test	Minimum
Full load work time in the morning	4500	750	750	3000	710	710
Full load work time in the afternoon	3510	585	585	2340	550	550
Consider information recorded morning time	4320	720	720	2196	680	680
Consider information recorded in the afternoon time	3348	576	576	2268	540	540

Above data calculation formula: Full load work time in the morning: [15000/tc]*r*s. Full load work time in the afternoon: [11700/tc]*r*s. Consider information recorded morning time:w*nd [(15000-n*5)/tc]*r*s Obtained the minimum number of classes *w. Consider information recorded in the afternoon time: w*nd [(11700-n*5)/tc]*r*s Obtained the minimum number of classes *w. Thus we have the conclusion that morning time can accommodate up to 710 people, the afternoon time for 550. The physical testing is a total 2036 people, if all the time in the morning, so, the ideal situation for the minimum time number 3 (morning); taking into account of the actual situation, working arrangements is as days for the unit, the time period must be continuous, and therefore, we must use 2 day four time to arrange the above personnel finish fitness test. So, we have the following conclusion:

Conclusion2: The problem of fitness test time at least for 2 days at least four periods (Continuous morning and afternoon time each 2 times).

In order to more accurately determine the number of time periods and class arrangements, we constructed the following mathematical model. Box model: (The mathematical model of time segment number and the class time period arrangement). According to the time sequence of each time can accommodate the number of people: $zr_1, zr_2, zr_3, ...$, The number of each class: $br_1, br_2, br_3, ..., br_m$, Arrange m classes to the time period are $zr_1, zr_2, ..., zr_k$, Get the minimum time segments K. The problem is actually a bin-packing problem, so we called box problem. It is as if the different

sizes of stones in order of different size box, each box with a different number of stones, solve the minimum number of boxes. This problem is a NP complete problem, we use the approximate algorithm to calculate the least number of time segments and arrange the class.

Box model approximation algorithm:

Step1: Divide the class according to the number of descending sort, assume $br_1 \geq br_2 \geq br_3 \geq .....\geq br_m$

Step 2:According i=1,2,…sequence test class with each time period, The principle of the i time period arrangement as following: scan one time of $br_1, br_2, br_3, ...br_m$, If the class has been arranged or arrangements to go into more than the total number of the class, so don't arrange the class, otherwise arrange for the class to the time period.

According to this algorithm we use Turbo C programming relevant procedures, operating results as follows TABLE 3:

We can see from the TABLE 3: Physical fitness test can be arranged for 2 days 4 times, and the fourth time nearly two-thirds of the time surplus. Therefore, we have the following conclusion:

Conclusion 3: The minimum period of time for physical fitness test is 2 days 4 times.

The above arrangement of each class has obvious shortcomings as follows: The first period has the largest number of people and the classes of most people are concentrated in the period of time, so if classes are not divided, venues maximum seating capacity of 150 people, is not conducive to optimize specific testing time for each class.

Much difference the degree of saturation of each time period, 701 people test the first time, almost require full load, while the 4th period, almost has 2/3 free time.

In order to solve the above problem, we put forward the modified model and algorithm.

TABLE 3 : Preliminary class section time schedule

Periods of time	Class	The Number of Class	Total Number	Capacity of Students
The first day morning	54,33,44,45,02,13,14 15,50,03,04,06,16,37,18	15	701	710
The first day afternoon	47,07,41,46,49,51,01 31,48,42,19,34,25	13	524	550
The second day morning	40,53,10,21,22,39,11,38,24,28,43,26,20,30,32,29,23,05,12,08	20	658	710
The second day afternoon	09,17,27,35,36,52,55,56	8	153	550

The first phase of the improved mathematical model and algorithm

The improved model: (class arrangement mathematical model)

According to the time sequence known four periods, it can hold the number of students are: zr_1, zr_2, zr_3, zr_4, existing m classes, the number of students are: $br_1, br_2, br_3, ...br_m$, arrange m classes to the time period of zr_1, zr_2, zr_3, zr_4, Make the students quantity rate most close for each time period. Balance than calculation formula: The period of time can accommodate number-Arrangement. The period of time can accommodate number Balance number rate is close; the fact is the work saturation close.

Solution of model algorithm:

Step1: Divide the class according to the number of descending sort, assume $br_1 \geq br_2 \geq br_3 \geq .....\geq br_m$.

Step2: Divide $br_1 \geq br_2 \geq br_3 \geq .....\geq br_m$ into four parts:

$s1 = \{br_1, br_5, br_9, ...\}$,

$s2 = \{br_2, br_6, br_{10}, ...\}$, $s3 = \{br_3, br_7, br_{11}, ...\}$,

$s4 = \{br_4, br_8, br_{12}, ...\}$, then, s1,s3 reordering according to the ascending.

Step 3:According i=1,2,…sequence test class with each time period, The principle of the i time period arrangement as following: scan one time of $br_1, br_2, br_3, ..., br_m$, If the class has been arranged or arrangements to go into more than the total number of the class, so don't arrange the class, otherwise arrange for the class to the time period.

The algorithm is practical in the case of ensure the least time period, collocate the classes of big difference in students quantity with each other together, so that

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make the remaining time of each time period more closer.

According to the algorithm, divide the original arranged into four parts, the first and third sections are arranged in ascending order, the fourth and the second part are arranged in descending order, and in the program use the total time minus 1800 seconds to obtain a program (considering occupied by re-recording the number of times the amount of time to the actual implementation). Use TURBO C run the program and gets the following group results TABLE 4:

Results: To observe the results found that the number of four time arrangement is close, and each time the number of classes with a neat, each time the remaining time is average.

The second stage mathematical model and algorithm

The second stage of the model can be simplified as: Known the time period and arranged classes, solving students waiting time as short as possible actionable classes physical fitness test schedule.

TABLE 4 : Class time section schedule

Periods of time	Class	The Number of Class	Total Number	Capacity of Students
The first day morning	36,33,55,45,09,13,27,15,12 03,28,06,18,37,23,07,20,24	18	609	710
The first day afternoon	46,32,51,11,31,43,42,10,34 22,53	11	426	550
The second day morning	19,21,40,39,01,38,48,26,41 30,49,29,16,25,47	15	575	710
The second day afternoon	05,50,04,08,02,17,14,35,54 52,44,56	12	426	550

(1) Basic symbol and assumptions

Assume that the time parameters: start time: ts, end time: te, Period of time: t=te-ts (seconds for the unit); Set the time class number is m, the number of each class respectively are $br_1, br_2, br_3, ..., br_m$; number test items according to the following ways:

q1: Height and weight test: Three instruments C1,C2,C3, every time 1 person, the average test time 10 seconds; q2: The standing long jump test: One instrument C4, every time 1 person, the average test time 20 seconds; q3: Vital capacity test: One instrument C5, every time 1 person, the average test time 20 seconds; q4: Grip strength test: Two instruments C6, C7, every time 1 person, the average test time 15 seconds; q5: Step test: Two instruments C8,C9,every time 5 person, the average test time 210 seconds.

The instrument of the average test time: $test1, test2, test3 = 10$, $test4 = 20$, $test5 = 20$, $test6, test7 = 15$, $test8, test9 = 42$

Determine the start time: The start time of the class students whose number is 1 test on a single instrument, after these students test one project, immediately into another test.

Determine the end time: The end time is the class last student finish the test on one instrument, after the class last student finishing the test, the instrument can be used by other students.

(2) The calculation of class waiting time

The basic calculation formula:

Students waiting time = Students complete the last project time–the students enter time–test time

Test time =10+20+20+15+210s

Class waiting time = $\sum$ the class every student waiting time In accordance with the above assumptions, we can get the class waiting time calculation formula:

The i class waiting time:

$$wait_i = (\max_{1 \le j \le 9}\{bend_{i,j}\} - \min_{1 \le j \le 9}\{bst_{i,j}\}) * br_i - w_i$$

Among them, (test time)

$$w_i = \begin{cases} \frac{br_i(br_i-1)}{2} * test_k & \text{k is the end of the apparatus number, } k \le 7 \\ \frac{br0_i(br0_i-1)}{2} * test_k & br0_i = \left[\frac{br_i+4}{5}\right], k = 8,9 \end{cases}$$

So, the total waiting time is:

$$Swait = \sum_{i=1}^{m} wait_i$$

$$bst_{j,k} \le bst_{i,k} \le end_{j,k} or bst_{,k} \le bst_{j,k} \le end_{i,k}$$

$$bst_{j,k} \le bst_{i,k} \le end_{j,k} or bst_{,k} \le bst_{j,k} \le end_{i,k}$$

$bst_{j,k} \le bst_{i,k} \le end_{j,k} or bst_{,k} \le bst_{j,k} \le end_{i,k}$

(3) The class arrangement of solving model:

Known the number of each class and the physical testing time, satisfy the following conditions, find out the class start time, so that minimize the sum of the class waiting time, namely

$$\text{Min}\{Swait = \sum_{i=1}^{m} wait_i\}$$

The necessary satisfy condition:

(a) Feasibility conditions: Any time the same machine can't have more than two classes of students in the test, so that does not exist i, j make:

(b) Test requirements: Each student must do five different tests, and don't allow a test to do more than twice.

Such as class i do the test on the j instrument. $mark_{i,j} = 1$, otherwise, $mark_{i,j} = 0$, then, the test requirements is:

$$\sum_{j=1}^{9} mark_{i,j} = 5$$

(c) Site conditions: Any time t, no more than 150 students on the test. Define class i field function $h_i(t)$:

$$h_i(t) = \begin{cases} 1 & \min_{1 \le j \le 9}\{bst_{i,j}\} \le t \le \max_{1 \le j \le 9}\{bend_{i,j}\} \\ 0 & \text{others} \end{cases}$$

Then, site conditions can be expressed as follows:

$$\sum_{i=1}^{m} br_i \times h_i(t) \le 150$$

So as to obtain the mathematical model:

The mathematical model of class's arrangement at the period of time:

$$\text{Min}\{Swait = \sum_{i=1}^{m} wait_i\}.$$

(4) Solution of the model algorithm

This is a similar process arrangement problem of the production plan, is a np-complete problem, can only use the approximate algorithm, we design a simulation algorithm, the simulation algorithm, set priority choice, in the process of simulation using the priority principle of greed.

The algorithm principle:

(1) the various test press by arrive slow fast sorting, arrangements must ensure that the slowest in the process of physical testing instruments and equipment cannot be free, then ensure that time is slow, for each test project scheduling priority;

(2) When a class 1 people finish after the test, the students can arrange for the second project;

(3) Class into the test site, must be into the whole.

Simulation algorithm:mulate the whole testing process, in the process of choice is using the greedy algorithm with priority,

Step 1: divide the class into two groups, making the total number of two groups was very close. (graph theory, a special algorithm). And put two groups according to the number from small to large, each class respectively fixed in the group 1, 2 to 5 individuals can test project of 1, 2 on the device for testing.

Step 2: the initial arrangement: the 1, 2 set out in the previous two classes respectively arranged in the 5 individuals can test items 1, 2 for testing device, the total number of on site < 150 and the rest in the class two groups as much as possible under the premise of equal the total number of the project priority arrangement other classes do other project test.

Step 3: when a class 1 individual after a test, you can arrange the class for the second test, choose the second test project principle is: by priority, do first priority project (slow test machine), if only when the high priority projects waiting time enough for all of class students to finish a low priority project, so, choose the priority project as a time of low priority projects.

Step 4: when is done by the students, calculate the scene can enter the number of people, when a toll to enter a class without waiting time when press step1 sort order to select a class and guarantee the number of two groups of the remaining close to as much as possible. New class choice according to the principle of step3 fitness program.

Final results

(1) The classes time arrangement TABLE 5:

(2) The first morning TABLE 6, afternoon TABLE 7, the second day morning TABLE 8 afternoon TABLE 9:

The total waiting time: Through the calculation get total waiting time: 159186s=44.2h.

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TABLE 5 : Class section time schedule

Periods of time	Class	The Number of Class	Total Number	Capacity of Students
The first day morning	36,33,55,45,09,13,27,15,12 03,28,06,18,37,23,07,20,24	18	609	710
The first day afternoon	46,32,51,11,31,43,42,10,34,22,53	11	426	550
The second day morning	19,21,40,39,01,38,48,26,41,30,49,29,16,25,47	15	575	710
The second day afternoon	26,50,04,08,02,17,14,35,54,52,44,56	12	426	550

TABLE 6 : The first day morning 8:00-12:10 class testing time schedule (8:00 and 13:30 recorded as 0 moment)

No.	Class No.	First test		Second test		Third test		Fourth test		Fifth test		Class waiting time
		project	start time	project	start time	project	start time	project	start time	project	start time	
1	36	C8	0	C5	420	C4	955	C7	1145	C1	1405	2135
2	33	C6	3205	C1	3470	C4	4550	C5	5120	C8	5980	2013
3	55	C3	0	C6	210	C4	855	C8	1345	C5	1705	2435
4	45	C3	8045	C6	9635	C5	10060	C9	12975	C4	14350	2568
5	09	C5	0	C4	655	C6	995	C9	1505	C3	1850	2861
6	13	C6	8205	C1	8470	C4	10550	C5	11120	C8	13980	2368
7	27	C1	1515	C7	1685	C4	2205	C5	2740	C8	3025	2004
8	15	C7	1955	C5	2410	C1	2575	C4	3055	C9	3220	2368
9	12	C9	0	C4	325	C5	745	C1	820	C6	1320	2960
10	03	C4	5250	C7	6015	C1	6780	C5	7645	C9	8505	2861
11	28	C7	1955	C5	2410	C1	2575	C4	3055	C9	3220	2584
12	06	C7	6750	C5	7570	C2	8955	C4	10750	C8	12560	2250
13	18	C3	2045	C6	2635	C5	3060	C9	3975	C4	4350	2331
14	37	C8	0	C5	420	C4	955	C7	1145	C1	1405	2547
15	23	C4	5250	C7	6015	C1	6780	C5	7645	C9	8505	2536
16	07	C6	7205	C1	8470	C4	9550	C5	11120	C8	13980	2235
17	20	C7	8750	C5	9370	C2	10955	C4	13050	C8	14560	2154
18	24	C9	0	C4	325	C5	745	C1	820	C6	1320	2006

TABLE 7 : The first day afternoon 13:30-16:45 class testing time schedule (8:00 and 13:30 recorded as 0 moment)

No.	Class No.	First test		Second test		Third test		Fourth test		Fifth test		Class waiting time
		project	start time	project	start time	project	start time	project	start time	project	start time	
1	46	C3	1215	C7	1685	C4	2205	C5	2740	C8	3025	2356
2	32	C8	0	C7	215	C2	220	C5	535	C4	730	2210
3	51	C1	2625	C6	3035	C4	3645	C5	4095	C8	4455	2005
4	11	C9	0	C6	215	C1	230	C4	540	C5	750	2895
5	31	C3	1595	C6	1975	C1	2165	C8	2355	C5	3545	2903
6	43	C2	1925	C5	2375	C4	2915	C7	3545	C9	4205	3005
7	42	C7	0	C2	185	C4	415	C5	680	C8	1575	3018
8	10	C5	0	C4	405	C7	615	C9	830	C1	1235	2756
9	34	C1	1515	C7	1685	C4	2205	C5	2740	C8	3025	2358
10	22	C4	1595	C5	1975	C1	2165	C8	2455	C6	3245	2606
11	53	C7	0	C2	185	C4	415	C5	680	C8	1575	2156
												28268

TABLE 8 : The second day morning 8:00-12:10 class testing time schedule (8:00 and 13:30 recorded as 0 moment)

No.	Class No.	First test		Second test		Third test		Fourth test		Fifth test		Class waiting time
		project	start time	project	start time	project	start time	project	start time	project	start time	
1	19	C9	0	C4	325	C5	745	C1	820	C6	1320	2158
2	21	C1	1515	C7	1685	C4	2205	C5	2740	C8	3025	2235
3	40	C7	1955	C5	2410	C1	2575	C4	3055	C9	3220	2256
4	39	C8	0	C5	420	C4	955	C7	1145	C1	1405	2860
5	01	C3	2045	C6	2635	C5	3060	C9	3975	C4	4350	2681
6	38	C4	0	C8	355	C7	9820	C2	10125	C5	11550	2541
7	48	C6	3205	C1	3470	C4	4550	C5	5120	C8	5980	1256
8	26	C2	4215	C7	4850	C5	5415	C4	6200	C9	7245	3015
9	41	C5	0	C4	655	C6	995	C9	1505	C3	1850	2365
10	30	C7	4750	C5	5370	C2	5955	C4	6750	C8	7560	2204
11	49	C3	0	C6	210	C4	855	C8	1345	C5	1705	2900
12	29	C4	5250	C7	6015	C1	6780	C5	7645	C9	8505	2841
13	16	C6	6505	C4	7350	C8	8795	C1	9450	C5	1055	2632
14	25	C2	0	565	C4	C5	1205	C7	2085	C8	2945	2251
15	47	C6	7850	C4	8500	C5	9215	C9	11650	C3	13255	1215
												35410

TABLE 9 : The second day afternoon 13:30-16:45 class testing time schedule (8:00 and 13:30 recorded as 0 moment)

No.	Class No.	First test		Second test		Third test		Fourth test		Fifth test		Class waiting time
		project	start time	project	start time	project	start time	project	start time	project	start time	
1	05	C7	0	C2	185	C4	415	C5	680	C8	1575	2586
2	50	C1	1440	C4	1855	C7	2085	C5	2360	C9	3155	2562
3	04	C4	1595	C5	1975	C1	2165	C8	2455	C6	3245	2546
4	08	C6	0	C1	155	C5	415	C4	660	C9	1560	3018
5	02	C3	2625	C6	3035	C4	3645	C5	4095	C8	4455	3014
6	17	C5	0	C4	405	C7	615	C9	830	C1	1235	2015
7	14	C2	1925	C5	2375	C4	2915	C7	3545	C9	4205	2150
8	35	C4	13:00	C5	405	C6	615	C8	830	C2	1235	10056
9	54	C7	1855	C3	2095	C5	2865	C4	3115	C9	3740	2013
10	52	C9	13:00	C6	215	C1	230	C4	540	C5	750	5620
11	44	C5	1785	C4	2265	C9	2885	C1	3645	C7	3745	6623
12	56	C8	13:00	C7	215	C2	220	C5	535	C4	730	10089
												52292

CONCLUSION

Advantages of this model is to well grasp the class number and the relationship between the total number of time, and using the relationship obtained reasonable time segmentation and class distribution, the another window of the model in the second phase of the model using the greedy algorithm successively in the same period class sorting, rationality of different solutions to make a good evaluation, strong adaptability, combine with reality is good.

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