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Mathematical optimization model of round robin schedule arrangements in sports competition

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ABSTRACT

The schedule arrangement is of great importance in sports events. Because of the schedule arrangements issue in the 2012 London Olympics, Yu Yang and Wang Xiaoli, two badminton players from China, were sentenced disqualified for negative competition. It is thus clear that schedule arrangements largely affect the outcome of the game. Aiming at grouping single cycle in badminton competition, this study establishes relative mathematical model based on "Beagle" scheduling method and counterclockwise rotation method and puts forward the optimal schedule arrangements, providing theoretic reference for the reasonable arrangements in big games.

KEYWORDS

Beagle;
Schedule method;
Counterclockwise rotation method;
Badminton;
Schedule.

INTRODUCTION

With economic growth and the development of science and technology in Today's society, people's living standards continue to improve and sports competition has been raised to an increasingly important position in the growing tension of modern life. In track and field sports held in colleges, middle schools and primary schools in China, hand chorography schedules is the mostly used method, the arranging work of which is tedious and error-prone. In recent years, researches on automatic arrangement management of the track and field sports are in the ascendant. Former scholars have worked out a lot of research results of automatic arrangement management in games. And some software systems of automatic arrangement management in games have also emerged. The scheduling problem of sports games is a special kind of time planning problem. Time planning had been proved to be NP hard problem as early as in the early 1960s. The game scheduling algorithms currently used are heuristic search method, network optimization algorithm and D-schedule algorithm. All these methods possess the disadvantage that the algorithm is too complex and they do not completely solve the practical problems of the game scheduling problem. The success of the Beijing Olympic Games highly enhances the sports weight in people's lives and sports activities play an important role in their lives. And that fairness is especially important for these sports. Moreover, especially in confrontational round robin competition, the game schedules affect the results of the competition greatly.

At present, people lay less emphasis on game schedule and researches in this area are relatively less. In the 2012 London Olympics, two Chinese players Yu Yang and Wang Xiaoli have already received a qualifying status after winning the first two games, while the Chinese players of the other team have outlet with the second group integral. In this case, in order to preserve their strength and adjust tactics, they both chose not to go all out in the match, to avoid the "rush ahead" phenomenon among Chinese in later games. However, this kind of behavior is contrary to the Olympic Games "fighting spirit". As a consequence, both of them were canceled the qualification in the later competition. And Ping Pang top seed also missed the gold medal in the London Olympics. The main reason of all these regret is the game scheduling problem. So it can be seen that schedule arrangement for the game is very important. Aiming at the optimal game scheduling arrangement scheme, this study mainly solves the issue of fairness for sports game schedule arrangements based on mathematical method and offers theoretic references for the hommization development of reasonable arrangement for the big game.

MODEL ASSUMPTIONS AND SYMBOL DESCRIPTIONS

Model assumptions

(1) Assume that the strength of the competition team can be generally aware of, and the level of play is normal; (2) The competition is divided into groups, and grouping game system is single-cycle; the competition team do not lack in the race; (3) There are no matches between seeded players, and neither between unseeded players; (4) The grouping stage start at the same time and integral according to the winning points of each team.

Symbol descriptions

In order to facilitate problem solving, the description of the symbols is given as follows:

N	Indicates the number of participating teams
y_i	Each team's comprehensive index
m	The divided grades m of each team's comprehensive strength
C_m	Ornamental index
J_m	Popularity index or viewer's optimistic coefficient of the team
M	Means the upper limit of field times in the interval of two games for each team
a	Means the round times of the competition teams
x_i	The interval field times between adjacent two games $(i = 1, 2, 3 \cdots n)$
S	The standard deviation of field times in the interval of two games for each team
N	Indicates the number of participating teams
SUM	The sum of field times in the interval of two games for each team
d	The interval field times in all matches of each game
D	The interval field times in all matches of all game

PROBLEM ANALYSIS

As contestants all competes with other contestants in the round robin competition, the results can better reflect the level of the competition teams. With the application of ranking determination method, the rankings of the teams in the round robin can be reasonably calculated. Round robin includes single loop, double loop and packet loop. The following is to discuss about the round robin schedule arrangements based on the system realization of grouping single cycle.

Game scheduling algorithm

□Determination of the order of the game: sort in "Beagle" method. However, when two players or teams in the same group round robin are from the same team, the race order should make appropriate changes. According to the IBF method, players from the same team must first encounter in the match, to avoid the phenomenon that the same team players deliberately lose the game and cause unfair situation. For example, number 1 and number 2 players are from the same team, then the 1-round game should reverses with the 5-round game, i.e. the 5-round game begins at first and 1-round game begins at last. □Calculation of game rounds: when the number of participating people (team) is even, the number of rounds=the number of participating people (team)-1; for example, there are 6 teams participating in the single round robin game, then the number of rounds=6-1=5 rounds, i.e. a total of 5 final. When the number of participating people (team) is odd, the number of rounds=the number of participating people (team); for example, there are 5 teams participating in the single round robin game, then the number of rounds is 5. □ Calculation of field's times: Field times=the number of participating people or teams*(participating people or teams-1)/2. For example: there are 6 teams participating in the single round robin game, the field times to be held is: 6*(6-1)=15(field times). □Determination of round robin ranking: rank according to win times and team with more win times is at the front of the list. If the win times of the two sides are the same, the winner of the game between the two sides is at the frontier of the ranking list. If the win times of three (or more than three) sides are the same, determine the ranking according to the net winning fields, bureau and points in all matches of the three sides at this stage (group). Wherein, provided that win times of two sides from the three sides are exactly the same (net win fields, bureau and points), the winner of the game between the two sides is at the frontier of the ranking list. If the net winning points of three sides (or more sides) are exactly the same, then determine the arrangement of the ranking in balloting method.

The number of teams to be scheduled for the grouping round robin game is N , and the number of people in each group is M, G represents the number of groups. (1) If $N/M=0$, $G=N/M$. (2)If $N/M>0$, $G=N/M+1$. And L,S represent the round number (or total round number) and field times in each group and round in grouping round robin game ofteams, then:

(1) If $M/2=0$, $L=M-1, S=M/2$; (2) If $M/2=1$ $L=M, S=(M+1)/2$, and it has a bye; (3) T represents total field times of all matches, then $T=G\times M\times(M-1)/2$.

Suppose $1\rightarrow M$ means the seeds' sequence number in each group. The commonly used methods are "Beagle" scheduling method and counterclockwise rotation method; the latter means that keep number 1 place fixed while rotating all other places. The "Beagle" scheduling method is used in the following test with four players in each group.

"Beagle" scheduling method

The problem of the rotation method that keep number 1 place fixed while rotating all other places, can be solved by "Beagle" scheduling method. When the number of participating teams is odd number, the application of "Beagle" scheduling method can avoid the unreasonable phenomenon that the second round bye team will always competes with the former round bye team in every field from the fourth round of the game. When the number of participating teams is even number, in "Beagle" scheduling method, the participating teams are divided into two parts (when the number of participating teams is odd number, use a number "0" at the end to form a even number of participating teams). The first half of the teams is numbered from 1, and is written on the left from the top; the numbers of the second half of the teams are written on the right from the top. Then connect the relative numbers with a line, i.e. the first round of the competition. In the second round of the competition, the number on the upper right corner of the first round is moved to the upper left corner; and it is removed to the upper right corner in the third round; and so on. In other words, when the number of round times is odd, "0" or the maximal number is on the upper right corner; when the number of round times is even, "0" or the maximal number is on the upper left corner, as shown in TABLE 1.

TABLE 1 : "Beagle" scheduling method ($N=4$)

I	II	III
1-4	4-3	2-4
2-3	4-2	3-1

The number 1 place is fixed and the rotation methods of other places are similar; just need to define two arrays: $A=\{1,\cdots,M-1\}$ $B=\{M/2+2,\vdots,M-1,1,\cdots,M/2+1\}$,

Which control the position transformation of odd number round and even number round respectively? When the number of round is odd, participating player 1 is seen as No.1 player and the last element in array A is selected as participating player 2 team codes. When the number of round is even, participating player 2 is seen as No.1 player and the last element in array B is selected as participating player 1 team code. Such is the realization of round robin grouping for players. When the grouping work is finished, for manual balloting grouping method, the group sign and number sign of the balloting results are according filled in the above generated Against TABLE; for automatic computer balloting system, the system updates the participating player 1 team code and participating player 2 team code of the group players according to the seed serial numbers, which realizes the grouping of round robin competition.

MODELING AND SOLVING

Analysis of the actual problem shows that, whether the rest and reorganization time between two field games for each team are equal in single round robin match plays a decisive role for the winning or losing of the game. First assume that there are five participating teams and a game schedule that there is at least one field game interval between two games for each team, is given. As the number of participating team is small, an ideal game schedule can be obtained by means of excluding-assuming method. Suppose that the five teams are respectively defined as team *A,B,C,D,E* and the total field times of the five teams in the single round robin match is $x=\frac{n(n-1)}{2}$. Then the total field times of the five teams is $x=\frac{5*(5-1)}{2}$.

There are five teams competing in the game. As the five teams have no obvious characteristics of the order, there are totally $C_5^2=10$ kinds of team composition possibilities in the first game. Suppose that team *A,B* play the first game. In order to meet the condition that there is at least one field game interval for each team between two field games, so for the second game, only two teams chosen from the other three teams *C,D,E* can play the second game. And there are three choices totally, C_3^2, i.e. *CD, CE, DE*. Suppose that team combination *CD* plays the second game; under the same restraining conditions as above, only team *A,B,E* can participate in the third game, and the team combination is *AB,AE, BE*. It can assume that the team combination of the third game is *EA*. Because it is single round robin between the teams, so there is only a game between any two teams; i.e. for any team, it will not encounter with another team in the following competition once has competed with the team. By parity of reasoning, the game schedule arrangement hereafter can be *BC, DE, AC, BD, EC, AD, BE*. Therefore, the total field times according with relative conditions is $10\times3\times2\times2\times2=240$, as shown in Figure 1.

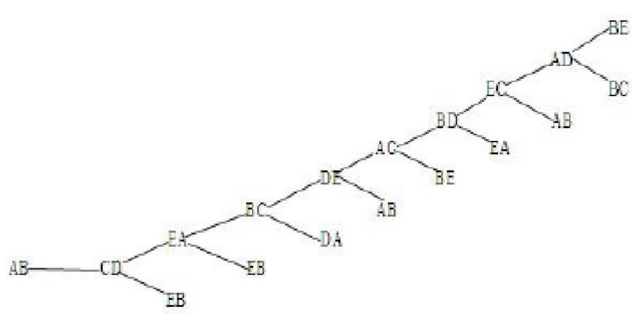

Figure 1 : Game schedule diagram

Because the game field times is less for five participating teams, the following form schedule can be transformed, from which the interval field times between two field games can be told intuitively and clearly, as shown in TABLE 2.

TABLE 2 : Interval field times of the match

	A	*B*	*C*	*D*	*E*	Interval field times between two field games
A	*X*	1	6	9	3	1, 2, 2
B	1	*X*	4	7	10	2, 2, 2
C	6	4	*X*	2	8	1,1,1
D	9	7	2	*X*	5	2,1,1
E	3	10	8	5	*X*	1, 2,1

The accuracy of assuming-excluding method is tested by utilizing *Matlab* programming. The programming can work out the competition situation of the overall 240 field games. Only by finding out the schedule arrangement corresponding to the above analysis, it will be able to prove the accuracy of this method. TABLE 3 shows the corresponding results determined through *Matlab* software. The schedule arrangement for five participating teams in 5 rounds and total 10 field games is shown in TABLE 3.

TABLE 3 : Schedule arrangement for five participating teams

1-2	5-1	4-5	2-4	1-4
3-4	2-3	1-3	5-3	2-5

As can be seen from TABLE 3, the result is the same with that of assuming-excluding method, demonstrating that this method is suitable for situations with less participating teams.

To make the match as fair as possible under the condition that there is at least one game interval between two games for each team, determine the upper limit of interval field times between two games. The number of participating teams is N and make the game as fair as possible for each team. And one of the measurable indicators of match fairness leis in: whether the rest time between the interval of two games for different teams are equal or of great different. Therefore, by counterclockwise rotation method, first the participating teams in this match are numbered as A, B, CD……with letter and as 1, 2, 3, 4…… then number 1 team is fixed, arrange the teams into two arrays with the left from top to bottom and the right from bottom to top.

In order to determine the race order, first arrange the match field according to rotation method. By research and speculation, bye situation will occur in odd number, while even number will not. So the discussion should be divided into two parts according to odd number and even number (when $n \leq 4$, the upper limit of interval field times between two games for each game is 0, which will not be discusses here):

(1) When *N* is an even number, the analysis of upper limit of interval field times between two games for each team is shown as follows. □ When *N*=6, the total number of games is 15 according to the algorithm. The rotation of game order is shown as TABLE 4 and the game schedule and interval field times are shown as TABLE 5.

TABLE 4 : Game order rotation of six participating teams in single round robin game

Round one	Round two	Round three	Round four	Round five
1-----2	1----3	1----6	1----5	1-----4
3-----4	6----2	5----3	4----6	2-----5
6-----5	5----4	4----2	2----3	3-----6

TABLE 5 : Game schedule and interval field times

	1	2	3	4	5	6	Interval field times between two games
1	X	13	10	7	4	1	2,2,2,2
2	13	X	6	11	2	9	3,2,1,1
3	10	6	X	3	8	14	2,1,1,3
4	3	11	3	X	15	5	1,1,3,3
5	4	2	8	15	X	12	1,3,3,2
6	1	9	14	5	12	X	3,3,2,1

As can be seen from TABLE 5, when *N*=6, the upper limit of interval field times between two games for each game is 1. Thus through programming, when= 8.10,...2*n*, et al. even numbers, repeat the calculation as to calculate *N*=6 the upper limit. Then the relationship between participating teams N and the upper limit of interval field times between two games for each team *M* is shown as TABLE 6.

TABLE 6 : Participating teams and the upper limit of interval field times between two games for each team

Number of participating teams N	6	8	10	12	…
Upper limit M	1	2	3	4	…

Therefore, from TABLE 6 the following law can be speculated: when *N* is even number, the upper limit of interval field times between two games for each game is: (*N*/2)-2; when *N*=100, by programming the upper limit of interval field times between two games for each game is 48. And calculating by the deduced formula, when *N*=100, by programming, the upper limit of interval field times between two games for each game is also 48. Thus the correctness of the formula is verified.

(2) When *N* is an odd number, the analysis of upper limit of interval field times between two games for each team is shown as follows.

When *N*=5, the calculated total field times according to related formula is 10, as shown in TABLE 7:

TABLE 7 : The round table when $N=5$

Round one	Round two	Round three	Round four	Round five
1-5	1-0	2-1	2-0	3-2
2-4	5-2	3-5	1-3	4-1
3-0	4-3	4-0	5-4	5-0

As can be seen from TABLE 7, when *N*=5, the upper limit of interval field times between two games for each game is 1. Thus through programming, when N=7,19,...,2*n*+1, et al. odd numbers, repeat the calculation as to calculate the upper limit. Then the relationship between participating teams N and the upper limit of interval field times between two games for each team *M* is shown as TABLE 8.

TABLE 8 : Participating teams N and upper limit of interval field times between two games for each game

Number of participating teams N	5	7	9	11	…	49	…
Upper limit M	1	2	3	4	…	23	…

Therefore, from TABLE 8 the following law can be speculated: when *N* is odd number, the upper limit of interval field times between two games for each game is:(*N*-3)/2; when *N*=99, by programming the upper limit of interval field times between two games for each game is 48. And calculating by the deduced formula, when *N*=99, by programming, the upper limit of interval field times between two games for each game is also 48. Thus the correctness of the formula is verified.

CONCLUSIONS

In real life, we often encounter the problem of game schedule arrangement. And whether schedule arrangement is fair, determines the outcome of both teams to some extent. In order to solve such problems, a counter-clockwise rotation is adopted to arrange the schedule. In counter-clockwise rotation method, the most exciting and most important game affecting the competition result is arranged at the final round in the race order. With an appropriate collocation for each round, there is always a close game in each game to maintain a tense atmosphere. This method gets a wide range of applications in the sports scope and is suitable for a basketball game, a single round robin game of TABLE tennis and badminton competitions.

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