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Motor Vehicle Maintenance Scheduling Model Based on Genetic algorithm

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ABSTRACT

To solve the problem of EMU maintenance planning time, we established a hybrid linear programming model based on adaptive genetic algorithm. According to the different levels of bullet train maintenance and the different arrival time, the constraint conditions are found, and the overall minimum maintenance time is taken as the objective function. Then the problem is transformed into a hybrid Flow-shop scheduling problem with unique process constraints, and an adaptive genetic algorithm is used to solve it again. It is concluded that the total maintenance takes 1125 minutes, and no blockage occurred in all EMU during the maintenance period. To provide a consistent basis for bullet train maintenance time and scheduling.

Keywords: Linear programming; Genetic algorithm; Hybrid; Flow-shop; Train maintenance

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1. Introduction

Full and high efficiency is the fundamental requirement of high-speed railway EMU operation [1]. EMU maintenance is an essential means to ensure the safe and efficient service of EMU. The optimization of the EMU maintenance plan is of great significance to improve the EMU operation efficiency and reduce the EMU maintenance cost. at the same time, it can provide a decision-making basis for the optimal allocation of maintenance capacity and the number of spare cars. The place responsible for the maintenance and maintenance of the bullet train is called the EMU operation group, and 50 EMU have been built in China [2]. the support of EMU is divided into different maintenance levels, different grades correspond to different processes, and each method of different types of EMU takes different time [1-3].

To dispatch the incoming train, to minimize the time required. For this reason, this paper established a train maintenance scheduling model based on a genetic algorithm, obtained the objective function and constraint conditions according to the requirements, and used a genetic algorithm to solve it to provide a relevant basis for bullet train maintenance time and scheduling [4, 5].

2. Problems to be solved

According to the running time, course and maintenance cycle of the train, the maintenance of EMU is divided into different maintenance levels, and various maintenance levels correspond to different process combinations, as shown in Table 1. There is 1 workshop in the process a, b and c, 3 workshops in process d and 2 workshops in e, and time consumption is the same in different workshops in the same process. The time required for each operation of different types of motor cars is given. The total time required to overhaul these trains is calculated according to the information of the trains arrived [6].

Table 1 Arrival information of motor cars, types of maintenance and combination of working procedures

Arrival time	Type of motor car	Maintenance type	Corresponding process combination
0:16	CRH2	Ⅳ	a→c→d→e
0:47	CRH5	Ⅱ	a→b→c
1:22	CRH2	Ⅱ	a→b→c
2:00	CRH6	Ⅰ	a→b
2:20	CRH3	Ⅲ	a→b→d
3:05	CRH6	Ⅱ	a→b→c
3:31	CRH2	V	a→b→c→d→e

Table 2 Time required for various types of motor cars in different processes

Type of motor car	Process category (hours)				
	a	b	c	d	e
CRH2	1	2	1.5	4	7
CRH3	0.8	2.4	0.5	4.8	6.5
CRH5	1.3	2.5	1.5	3	6
CRH6	1	2.7	0.3	5	7

3. Establishment of mixed Linear programming Model

3.1 Determination of objective function

Let o, p, q, be the number of workshops in the three processes of, a,b,c , among which $o=1,2,3.$ $p=1,2,\cdots,8.$ $q=1,2,\cdots,5$, $r=1,2,3, s=1,2$. Let m,n is the serial number of the motor cars driven into the overhaul and the number of categories in the maintenance workshop, among which

$m=1,2,\cdots,7, n=1,2,\cdots,5$. To improve the overall maintenance efficiency of the incoming maintenance EMU of different types of bullet trains at different levels of maintenance, the objective function is determined as the shortest maintenance time of the whole EMU. Among them, T_{mn} indicates the end time of the EMU in the nth maintenance workshop [7], and the formula is as follows:

$$\min \max_{1\le m\le 7}\left\{\max_{1\le n\le 5}\left\{T_{mn}\right\}\right\}$$

3.2 Establishment of constraints

Establishment of bullet train type 0-1 matrix $K_{r\times m}$ coach. $K_{r\times m}$ means that the m-th EMU is an r-type bullet train. $r=1,2,3,4$ denotes the model of each type of motor car, for example, $r=1$, which is indicated as CRH2 EMU. $K_{rm}=0$ indicates that the m EMU is not a type r bullet train, and $K_{rm}=1$ is an r type bullet train. The specific formula is as follows:

$$K_{r\times m}=\left[K_{11} \quad \cdots \quad K_{1r}\right]_{r\times m} \quad \left(r=1,2,\cdots,4, m=1,2,\cdots,7\right)$$

Establishment of $L_{n\times r}$ repair data Matrix for various types of Motor cars. Let L_{nr} denote the processing time of the r-type motor car in the nth process. According to the given data, the corresponding matrix is established as follows:

$$L_{n\times r}=\left[L_{11} \quad \cdots \quad L_{1r}\right]_{n\times r} \quad \left(n=1,2,\cdots 5, r=1,2,\cdots,4\right)$$

The establishment of the relation matrix $E_{n\times e}$ repair between maintenance type and workshop 0-1Since motor cars with different maintenance levels enter different workshops in a different order, in which $e=1,2,3,4,5$ denotes the corresponding maintenance level. Example: $e=1$ indicates the maintenance level of grade I. As some workshop repairs may not be carried out at different levels take E_{ne} like 0 or 1, and the formula is as follows:

$$E_{n\times e}=\left[E_{11} \quad \cdots \quad E_{1e}\right]_{n\times e} \quad \left(e=1,2,\cdots,5, n=1,2,\cdots,5\right)$$

Where E_{ne}=1 means that workshop n will be used in the maintenance of level e, E_{ne}=0 which means that workshop n will not be used in the maintenance of level e.

Establishment of vehicle serial number and maintenance 0 to 1 type matrix $F_{e\times m}$ repair. Because the bullet trains entering the station at different times are not only different in time and model, but also have different types of maintenance. Therefore, a two-dimensional matrix of vehicle serial number and maintenance type is established, where $F_{em}=0$ means that the maintenance type of m-th motor car is not grade e, $F_{em}=1$ indicates that the type of maintenance of the m-th motor car is grade e.The formula is as follows.

$$F_{e\times m}=\left[F_{11} \quad \cdots \quad F_{1m}\right]_{e\times m} \quad \left(e=1,2,\cdots,5, m=1,2,\cdots,7\right)$$

The establishment of a time constraint $S_{m\times n}$ matrix. Because the time of the bullet train entering the inspection and repair station is not only different, its maintenance grade is different, and the maintenance time in each workshop is different due to different models. Therefore, the time constraint matrix is established according to the above four matrices and represents the processing time of the m-th measuring car in process n, and the formula is as follows:

$$S_{m\times n}=\left[\left(E_{n\times e}\cdot F_{e\times m}\right)\times\left(K_{r\times m}\cdot L_{n\times r}\right)\right]_{m\times n} \quad \left(\forall n,\forall r,\forall m,\forall e\right)$$

Establishment of constraints for entering the maintenance process. Let $t_m\left(t_1,t_2,\cdots t_m,\cdots t_7\right)$ denote the time point at which the m-th EMU enters the maintenance station, because it may need to queue up before entering the maintenance station. Therefore, the constraints can be established as follows:

$$t_m \le t_{ma} \quad (m=1,2,\cdots,7)$$

Whether the bullet train has entered the inspection station. Let A_m^{ij} denote whether the m-th car enters the j-th workshop of the I-th process, where means that the m-th car does not enter the j-th workshop of the I-th process, and when $A_m^{ij}=1$ indicates that the m-th car will enter the j-th workshop of the I-th process. Get the following constraints:

$$A_m^{ij}=\{0,1\}$$

Whether the bullet train occupies the inspection station. Let the value of B_m^{ij} indicating whether the m-th car T occupies the j-th workshop of the I-th process at any time. Get the constraint condition $B_m^{ij}=\{0,1\}$, When means that the m-th car T does not occupy the j-th workshop of the I-th process at any time; When $B_k^{ij}=1$ means that the m-th car occupies the j-th workshop of the i-th process at any time. According to the actual situation, there is $B_m^{ij}=0$ when the train has not entered or has been overhauled. t_{ij} T denotes the entry time of m EMU in the nth maintenance workshop, T represents any time, $T\in(0,+\infty)$.So the B_m^{ij} constraint is as follows:

$$B(T)_m^{ij}=\begin{cases}0 & T<t_{mn}\\ 1 & t_{mn}\le T\le T_{mn}\\ 0 & T>T_{mn}\end{cases} \quad (m=1,2,\cdots,7,n=1,2,\cdots,5)$$

Restrictions on the number of motor cars in the workshop. For T at any time, there will be at most one set of bullet trains in each workshop in the three types of maintenance procedures of a,b,c,d,e, so the constraints can be established as follows:

$$\sum_m B(T)_m^{ij} \le 1 \quad (T\in(0,+\infty),i=1,2,\cdots,5,\forall j)$$

The constraint of time cohesion. According to the requirements of the topic, the switching time between EMU is ignored. For any group of EMU, the end time of m in the previous workshop is the entry time of entering the next workshop. Therefore, the constraints are established as follows:

$$T_{m(n+1)}=t_{mn} \quad (m=1,2,\cdots,7,n=1,2,3,4)$$

The restriction of EMU entering the station. Any EMU m can only enter one workshop after each maintenance process, and some workshops caused by different maintenance levels do not pass through. We regard it as still passing, but the maintenance time is 0. Therefore, the inbound constraints are established as follows:

$$\sum_i A_m^{ij}=1 \quad (m=1,2,\cdots,7,\forall j)$$

Maintenance time constraint. S_{mn} indicates the processing time of the m-th EMU in process n. As different types of motor cars spend different time in different workshops in the same process, and different maintenance workshops with different maintenance levels, if the workshop in the next process is full, we need to wait in the original workshop. For any group of motor cars, it can be found that the stay time in different processes may exceed the maintenance time. Therefore, constraints can be established as follows:

$$T_{mn}-t_{mn}\ge S_{mn} \quad (m=1,2,\cdots,7,n=1,2,\cdots,5)$$

To sum up, the single-objective nonlinear programming model is established as follows:

$$\min \max_{1\le m\le 7}\left\{\max_{1\le n\le 5}\{T_{mn}\}\right\}$$

$$s.t.\begin{cases} S_{m\times n}=\left[\left(E_{n\times e}\cdot F_{e\times m}\right)\times\left(K_{r\times m}\cdot L_{n\times r}\right)\right]_{m\times n} \\ t_m \le t_{ma} \quad (m=1,2,\cdots,7) \\ A_m^{ij}=\{0,1\} \\ B(T)_m^{ij}=\begin{cases}0 & T<t_{mn} \\ 1 & t_{mn}\le T\le T_{mn} \\ 0 & T>T_{mn}\end{cases} \quad (m=1,2,\cdots,7,n=1,2,\cdots,5) \\ \sum_m B(T)_m^{ij}\le 1 \quad (T\in(0,+\infty)) \\ T_{mn}=t_{m(n+1)} \\ \sum_i A_m^{ij}=1 \\ T_{mn}-t_{mn}\ge S_{mn} \end{cases}$$

3.3 Application of Genetic Algorithm in Calculation of Motor Vehicle Maintenance Time

At present, this kind of NP problem is mainly solved by high-end algorithms [8]. An intelligent algorithm is needed to solve the problem. The neural network, simulated annealing algorithm, and genetic algorithm are all algorithms to solve this problem. Among them, the genetic algorithm is widely used. Therefore, a genetic algorithm is used as a method to solve the problem. The flow chart is shown in Fig. 1.

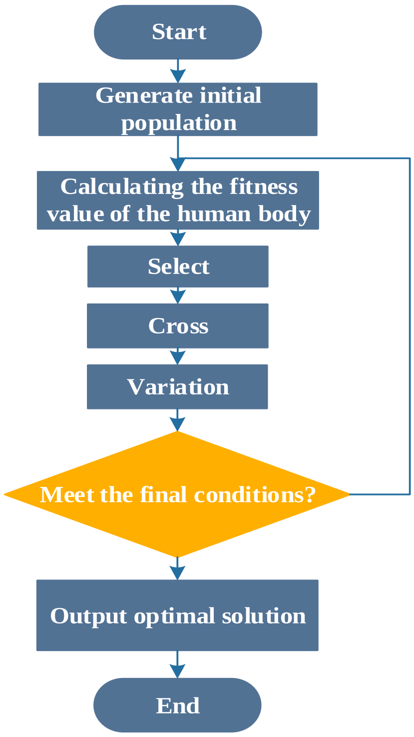

Fig. 1 Flow chart of the genetic algorithm

4. Results and result analysis

Based on the MATLAB platform, input the processing time and processing level of different types and different processes. The population size is N=50, the mutation probability is P=0.1, and the number of iterations is 1000. Five iterations are carried out by changing the number of iterations to solve the minimum completion time. The specific simulation results are as follows

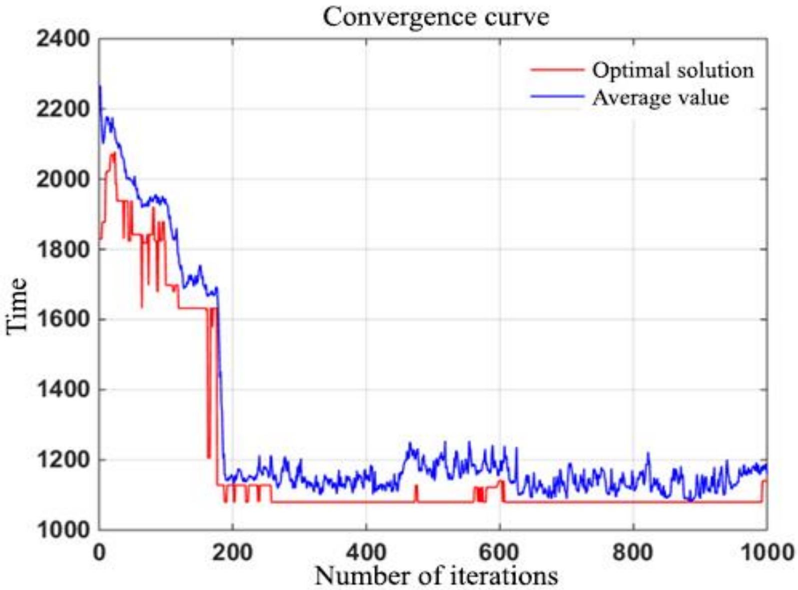

Fig. 2 Convergence result of genetic algorithm

As shown in Fig. 2, when the solution obtained by the number of iterations is the optimal solution. The last one leaves at 7:01 pm, and the total maintenance time is 1125 minutes. The Gantt chart was drawn using the genetic algorithm, as shown in Fig. 3.

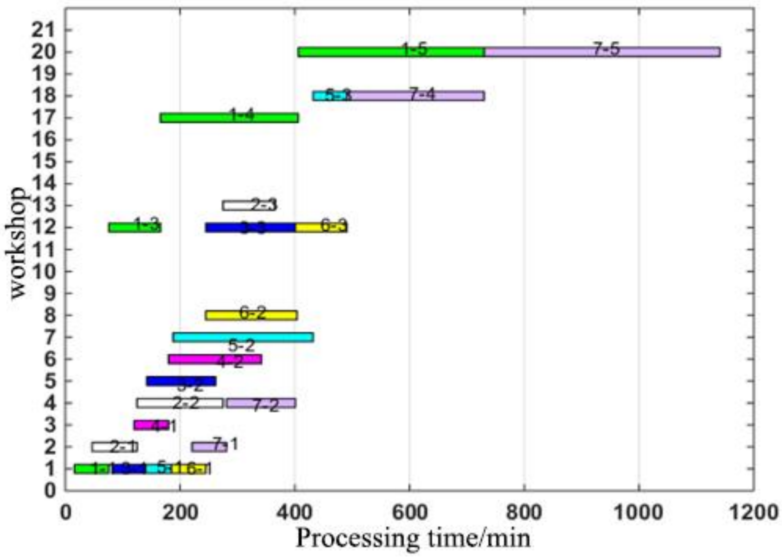

Fig. 3 Gantt chart of motor car maintenance time

As shown in Fig.3, the rectangles of seven different colors represent seven different EMU. The process of the motor car is explained by tagging m-n, where m represents the serial number of the motor car, and n represents the serial number of the process. Numbers represent the sequence of processes. The y-axis represents the 21 workshop serial numbers of 5 processes. The length of the color block in the Gantt chart represents the stay time of all types of motor cars in each process. The solution to the F-TSP problem under the genetic algorithm needs to constantly change the number of iterations to find a globally optimal solution.

5. Conclusion

The adaptive genetic algorithm model and the hybrid linear programming model are established. According to the different maintenance levels and arrival time, the minimum maintenance time is taken as the objective function, and the problem is transformed into a hybrid

Flow-shop scheduling problem with special process constraints, and the adaptive genetic algorithm is used to solve it again. It is concluded that the total maintenance takes 1125 minutes, and no blockage occurred in all EMU during the maintenance period. To provide a consistent basis for bullet train maintenance time and scheduling.

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