

Research on Receiving Routes and Departure Routes Assignment Problem in High-speed Railway Station Based on SFLA

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Abstract. The assignment problem of receiving routes and departure routes in high-speed railway stations is a complex multi-objective combinatorial optimization problem. According to the characteristics of receiving routes and departure routes, assignment model of receiving routes and departure routes in High-speed railway stations is set up. Shuffled Frog Leaping Algorithm (short for SFLA) is adopted to solve that model. As using SFLA, it could reduce the amount of calculation effectively, improve the execution speed of the algorithm and increase the diversity of solutions. And with its unique mechanism of exchanging and sharing information, the solving process is not easy to fall into local optimum, which is beneficial to search the global optimal solution. Using SFLA offers a new method to set up the assignment model of receiving routes and departure routes in High-speed railway stations.

1. Introduction

Train operation plan diagram is the core of the train operation plan. When preparing the train operation plan diagram, it is necessary to determine the routes of trains, the arrival time and the departure time of each station and the station task plan. The assignment of receiving routes and departure routes in stations relates to the utilization of receiving-departure tracks and the selection of receiving routes and departure routes in stations, which is the core of train operation in High-speed railway stations. The receiving routes and departure routes assignment in High-speed railway stations matters the safety of train, the punctuality of train operation and the realization of the high quality of service. In order to solve the assignment problem of receiving routes and departure routes in stations, the method of simulating artificial scheduling[1], the undirected graph with colored apexes transformed[2], genetic algorithm[3-5], 0-1 integer programming model[6-8], timed colored Petri nets[9] are adopted by many researchers. Under the premise of the given station structure and the given train operation plan diagram, the assignment model of receiving routes and departure routes in High-speed railway stations is set up. As SFLA is adopted to solve that model, it could reduce the amount of calculation effectively, improve the execution speed of the algorithm, increase the diversity of solutions and be beneficial to search the global optimal solution.



2. The Theory of SFLA

Shuffled frog leaping algorithm is a swarm intelligence algorithm which issues from the group information sharing and communication mechanism when simulating the process of frog foraging. The SFLA is a new heuristic swarm intelligence evolutionary algorithm. The realization mechanism of SFLA is to complete the solving process by simulating the coordination and information interaction which arises from the process of frog foraging in nature. Information transmission is based on the classification of ethnic groups in SFLA. The local evolution and recombination process are mixed together. It could make the combination of global information interaction and local evolutionary search effectively. It has efficient computing performance and excellent global searching ability.

Grouping operator and local position updating operator play a key role on the speed of convergence and execution in SFLA. It determines the performance and adaptability of the algorithm.

A. Grouping operator

Firstly, the initial population is composed of a set of solutions by initializing randomly. And then all frogs are arranged descending according to their initial fitness value and put into each meme group. Specific method is as follows: frogs are divided into meme groups in descending order according to the fitness values. The first frog enters the first meme group. The second frog enters the second meme group. As far as the Num. m frog enters the Num. m meme group. And then the Num. $m+1$ frog enters the first meme group. The Num. $m+2$ frog enters the second meme group. As far as all frogs are assigned. F_b represents the best frog in each meme group. F_w represents the worst frog in each meme group. F_g represents the best location frog in the whole population.

B. Local position updating operator

In every evolution process of meme grouping, the location of the worst frog could be adjusted. The specific adjustment methods are as follows:

The movement of frog:

$$D_i = rand() * (F_b - F_w)$$

Updating the worst location of frog:

$$F_w = F_w + D_i (D_{\max} \leq D_i \leq D_{\min})$$

$rand()$ is the random number between 0 and 1. D_{\max} is the maximum distance that allows the frog to move. If the worst frog could get a better location by the above process, the frog in original location will be replaced by the frog in new location and the worst frog will be updated. Otherwise F_b will be replaced by F_g . Repeating the above procedure and Updating the location of the worst frog using the formulas as follows:

$$D_i = rand() * (F_g - F_w)$$

$$F_w = F_w + D_i (D_{\max} \leq D_i \leq D_{\min})$$

If it could not get a better location frog using the above methods or the movement of the frog beyond the maximum moving distance in adjustment, the worst frog F_w will be replaced by a random solution. In this way, several times evolution processes are executed in each meme group. The worst location frog will be adjusted and updated. Normally, when the location of the best frog is no longer change or the algorithm achieves the number of the expected evolution, the algorithm stops and outputs the optimal solution. As the location of the worst frog is changed in each cycle and only the fitness of the worst frog could be improved that it is not all frog could be improved, it is helpful to improve the overall efficiency of the algorithm.

3. The Model of Receiving Routes and Departure Routes Assignment in High-speed Railway Stations

3.1 Model specification

Based on the known station layout diagram, the arrival time, the departure time, EMU operation plan and the train connection scheme, the assignment scheme of receiving routes and departure routes in High-speed railway stations will be researched.

3.2 Parameter definition

$Train$: The set of trains, $Train = \{train_i | i = 1, 2, \dots, m\}$, the trains orders by arrival time sequence.

m : The number of trains.

$Track$: The set of station tracks, $Track = \{track_j | j = 1, 2, \dots, n\}$.

n : The number of station tracks

O_{ij} : The state of the $train_i$ occupies the $track_j$, 0 or 1

$$O_{ij} = \begin{cases} 1 & \text{occupied} \\ 0 & \text{unoccupied} \end{cases}$$

T_{ij}^{arri} : The arrival routing time that $train_i$ enters $track_j$

T_{ij}^{dept} : The departure routing time that $train_i$ departs from $track_j$

T_{ij}^o : The interval time that $train_i$ occupies $track_j$

N_{ij}^{arri} : The routes amount of $train_i$ enters $track_j$

N_{ij}^{dept} : The routes amount of $train_i$ departs from $track_j$

p : The route number that $train_i$ enters $track_j$, positive integer, $p = 1, 2, \dots, N_{ij}^{arri}$

q : The route number that $train_i$ departs from $track_j$, positive integer, $q = 1, 2, \dots, N_{ij}^{dept}$

R_{ijp}^{arri} : The Num. p route that $train_i$ enters $track_j$

R_{ijq}^{dept} : The Num. q route that $train_i$ departs from $track_j$

S_{ijp}^{arri} : The state that R_{ijp}^{arri} is selected.

$$S_{ijp}^{arri} = \begin{cases} 1 & R_{ijp}^{arri} \text{ is selected} \\ 0 & R_{ijp}^{arri} \text{ is not selected} \end{cases}$$

S_{ijq}^{dept} : The state that R_{ijq}^{dept} is selected.

$$S_{ijq}^{dept} = \begin{cases} 1 & R_{ijq}^{dept} \text{ is selected by } train_i \\ 0 & R_{ijq}^{dept} \text{ is not selected by } train_i \end{cases}$$

R_{ij}^{arriB} : The basic route that $train_i$ enters $track_j$

R_{ij}^{deptB} : The basic route that $train_i$ departs from $track_j$

S_{ij}^{arriB} : The state that R_{ij}^{arriB} is selected.

$$S_{ij}^{arriB} = \begin{cases} 1 & R_{ij}^{arriB} \text{ is selected} \\ 0 & R_{ij}^{arriB} \text{ is not selected} \end{cases}$$

S_{ij}^{deptB} : The state that R_{ij}^{deptB} is selected

$$S_{ij}^{deptB} = \begin{cases} 1 & R_{ij}^{deptB} \text{ is selected} \\ 0 & R_{ij}^{deptB} \text{ is not selected} \end{cases}$$

T_e^{arri} : The arrival time of $train_e$

T_i^{dept} : The departure time of $train_i$

$T^{interval}$: The minimum interval time that the adjacent train occupies the same track.

3.3 Constraint conditions

(1) One Train only could occupy one track.

$$\sum_{j=1}^n O_{ij} = 1$$

$$\forall i \in \{1, 2, \dots, m\}$$

(2) The unique utilization of the receiving routes and departure routes.

$$\sum_{j=1}^n \sum_{p=1}^{N_{ij}^{arri}} S_{ijp}^{arri} = 1$$

$$\forall i \in \{1, 2, \dots, m\}$$

$$\sum_{j=1}^n \sum_{q=1}^{N_{ij}^{depi}} S_{ijq}^{depi} = 1$$

$$\forall i \in \{1, 2, \dots, m\}$$

(3) The task time interval constraint of receiving-departure track.

$$O_{ij} + O_{ie} \leq 1$$

$$\forall i, e \in \{1, 2, \dots, m\} \quad i < e$$

$$T_e^{arri} < T_i^{depi} + T^{interval}$$

$$j \in \{1, 2, \dots, n\}$$

(4) Consistency constraint of receiving routes, departure routes and the tracks.

$$O_{ij} = \sum_{p=1}^{N_{ij}^{arri}} S_{ijp}^{arri}$$

$$\forall i \in \{1, 2, \dots, m\}; \forall j \in \{1, 2, \dots, n\}$$

$$O_{ij} = \sum_{q=1}^{N_{ij}^{depi}} S_{ijq}^{depi}$$

$$\forall i \in \{1, 2, \dots, m\}; \forall j \in \{1, 2, \dots, n\}$$

3.4 Objective function

Objective function 1: the minimum sum of the travel time in station.

$$\min Z_1 = \sum_{i=1}^m \sum_{j=1}^n O_{ij} (T_{ij}^{arri} + T_{ij}^{depi})$$

Objective function 2: the maximum preference of the selected receiving route and departure route.

$$\max Z_2 = \sum_{i=1}^m \sum_{j=1}^n \sum_{p=1}^{N_{ij}^{arri}} S_{ijp}^{arri} W_{ijp}^{arri} + \sum_{i=1}^m \sum_{j=1}^n \sum_{q=1}^{N_{ij}^{depi}} S_{ijq}^{depi} W_{ijq}^{depi}$$

Objective function 3: the balanced utilization of receiving-departure tracks.

$$\min Z_3 = \sum_{j=1}^n \left[\sum_{i=1}^m T_{ij}^o O_{ij} - \frac{\sum_{i=1}^m T_{ij}^o}{n} \right]^2$$

Objective function 4: choosing the basic routes as possible.

$$\max Z_4 = \sum_{i=1}^m \sum_{j=1}^n S_{ij}^{arriB} + \sum_{i=1}^m \sum_{j=1}^n S_{ij}^{depiB}$$

4. Model Research on Receiving Route and Departure Route Assignment in High-speed Railway Station Based on SFLA

4.1 Realization steps

Step1: Population initialization. The number of given meme group is m . The maximum evolution times in meme group is M . For the Num. i frog $Frog(i)$, each sample is distributed randomly as initial classification. Calculating the location of frog $Frog(i).location[]$ and the fitness $Frog(i).fitness$ repeatedly, and then creates N Frogs.

Step 2: N frogs are arranged in descending order by fitness. And N frogs are divided into m meme group.

Step 3: The worst location frog in each meme group was executed the local position updating operator.

$$F_w = F_w + D_i (D_{-max} \leq D_i \leq D_{max}), \quad D_i = rand() * (F_b - F_w) \quad \text{or} \quad D_i = rand() * (F_g - F_w)$$

Step 4: All frogs are remixed in each meme group and then the total population is assembled of N frogs.

Step 5: Updating the best location frog F_g in the new population.

Step 6: Judging whether the procedure meets the end condition. If the procedure meets the end condition, the iterative procedure ends. Otherwise turn to step 2.

4.2 Flow chart

The flow char is as follows:

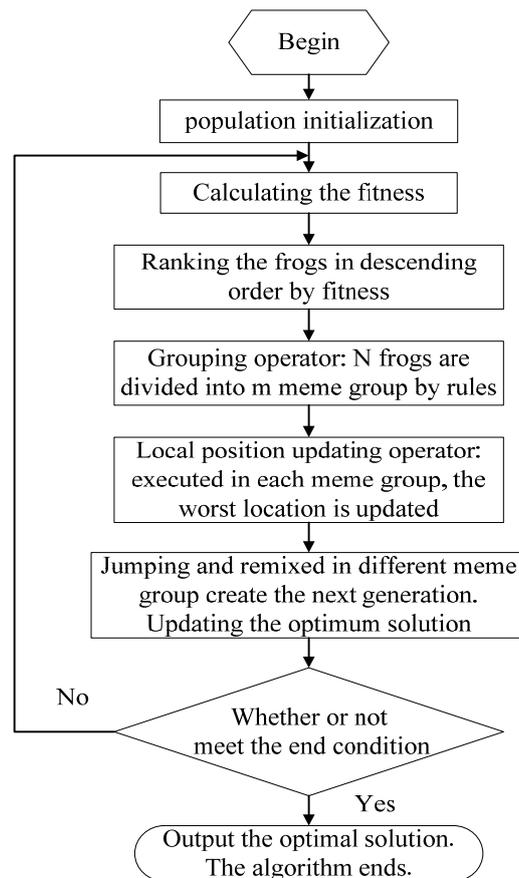


Fig.1 The SFLA application flow chart

5. Example and Results analysis

The above model and algorithm were adopted in a high-speed railway passenger station as an example. The receiving routes and departure routes assignment are simulated in this station from 10 am to 3 pm. There are thirty trains, ten down trains and twenty up trains. The down trains have priority to use IG, 3G and 5G. And IIG, 4G, 6G and 8G also could be used to receive and departure up trains. IG and IIG are the main tracks. The high-speed railway station graph is as follows:

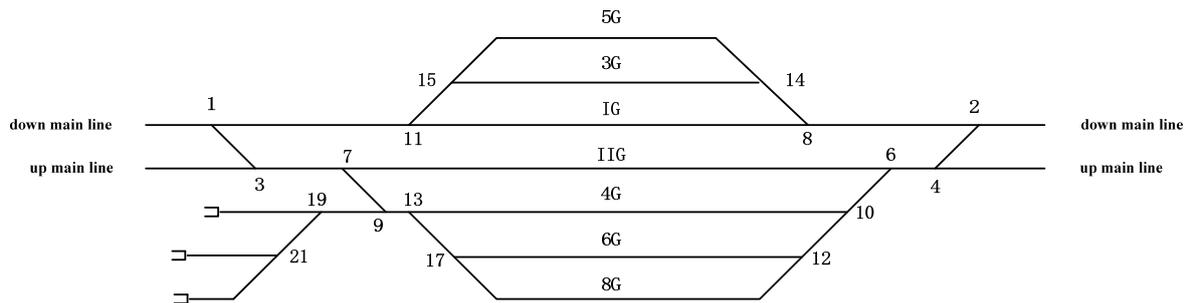


Fig.2 the high-speed railway station graph

According to the train operation plan diagram, the arrival time and departure time of thirty high-speed railway trains from 10:00 am to 3:00 pm is as follows:

Table.1 Train timetable from 10:00 am to 3:00 pm

Train Num.	Arrival time	Departure time	Train Num.	Arrival time	Departure time
G2	10:12	10:14	G9	12:25	12:25
G1	10:21	10:23	G24	12:32	12:34
G4	10:27	10:29	G11	12:39	12:39
G6	10:34	10:36	G26	12:37	12:39
G3	10:41	10:43	G13	12:34	12:43
G8	10:44	10:46	G28	13:08	13:10
G10	10:58	11:00	G30	13:20	13:22
G12	11:05	11:07	G32	13:33	13:33
G14	11:11	11:14	G34	13:49	13:51
G5	11:21	11:23	G36	14:10	14:12
G16	11:34	11:37	G15	14:33	14:35
G18	11:49	11:49	G38	14:35	14:37
G20	11:58	12:00	G17	14:39	14:41
G7	12:05	12:07	G40	14:52	14:54
G22	12:22	12:24	G19	14:55	14:55

The number of meme groups is 20. The maximum number of evolution in each meme groups is 600. The number of classification is 80. Using the assignment model of receiving routes and departure routes in high-speed railway station based on SFLA, the results are as follows:

Table.2 the assignment result of receiving routes and departure routes

Train Num.	Arrival time	Departure time	track	receiving route	departure route
G2	10:12	10:14	8G	4,6,10,12,8G	8G,17,13,9,7,3
G1	10:21	10:23	3G	1,11,15,3G	3G,14,8,2
G4	10:27	10:29	8G	4,6,10,12,8G	8G,17,13,9,7,3
G6	10:34	10:36	4G	4,6,10,4G	4G 13,9,7,3
G3	10:41	10:43	3G	1,11,15,3G	3G,14,8,2
G8	10:44	10:46	8G	4,6,10,12,8G	8G,17,13,9,7,3
G10	10:58	11:00	8G	4,6,10,12,8G	8G,17,13,9,7,3
G12	11:05	11:07	6G	4,6,0,12,6G	6G,17,13,9,7,3
G14	11:11	11:14	8G	4,6,10,12,8G	8G,17,13,9,7,3
G5	11:21	11:23	3G	1,11,15,3G	3G,14,8,2

G16	11:34	11:37	8G	4,6,10,12,8G	8G,17,13,9,7,3
G18	11:49	11:49	IIG	4,6,IIG	IIG ,7,3
G20	11:58	12:00	8G	4,6,10,12,8G	8G,17,13,9,7,3
G7	12:05	12:07	3G	1,11,15,3G	3G,14,8,2
G22	12:22	12:24	8G	4,6,10,12,8G	8G,17,13,9,7,3
G9	12:25	12:25	IG	1,11,IG	IG,8,2
G24	12:32	12:34	4G	4,6,10,4G	4G 13,9,7,3
G11	12:39	12:39	IG	1,11,IG	IG,8,2
G26	12:37	12:39	8G	4,6,10,12,8G	8G,17,13,9,7,3
G13	12:34	12:43	3G	1,11,15,3G	3G,14,8,2
G28	13:08	13:10	8G	4,6,10,12,8G	8G,17,13,9,7,3
G30	13:20	13:22	8G	4,6,10,12,8G	8G,17,13,9,7,3
G32	13:33	13:33	IIG	4,6,IIG	IIG ,7,3
G34	13:49	13:51	8G	4,6,10,12,8G	8G,17,13,9,7,3
G36	14:10	14:12	8G	4,6,10,12,8G	8G,17,13,9,7,3
G15	14:33	14:35	3G	1,11,15,3G	3G,14,8,2
G38	14:35	14:37	8G	4,6,10,12,8G	8G,17,13,9,7,3
G17	14:39	14:41	5G	1,11,15,5G	5G,14,8,2
G40	14:52	14:54	8G	4,6,10,12,8G	8G,17,13,9,7,3
G19	14:55	14:55	IG	1,11,IG	IG,8,2

From the above results, we can see that the receiving-departure tracks are balanced utilized. The basic receiving routes and departure routes are selected frequently. It can make the train travel time shorter in the station. The results correspond to anticipation. Shuffled frog leaping algorithm adopted to solve the assignment model of receiving routes and departure routes can meet the real-time, effectiveness and reliability requirement.

6. Conclusion

In this paper, according to the characteristics of receiving routes and departure routes, assignment model of receiving routes and departure routes in high-speed railway stations is set up. Shuffled frog leaping algorithm is adopted to solve that model. As SFLA's unique mechanism of exchanging and sharing information, it can better control the global and the local search capability simultaneously. The algorithm model could increase the diversity of solutions, improve the execution speed, reduce the amount of calculation effectively and not be easy to fall into local optimum. And the experiment results also show that SFLA adopted to solve the receiving routes and departure routes assignment problem has feasibility and availability. Using shuffled frog leaping algorithm offers a new method to set up the assignment model of receiving routes and departure routes in High-speed railway stations.

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