Improved Genetic Algorithm Based Passenger Flow Control in Subway

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Abstract This paper is in the background that improvement of organization for urban rail transit operation along with its rapid development is an urgent need. Aimed at solving the organization problem of mass passenger flow, passenger flow control in subway is analyzed. To increase the control quality and efficiency, the method of improved genetic algorithm is studied. Finally, the algorithm is applied to a case study to verify its validity.

Keywords Subway · Passenger flow control · Improved genetic algorithm
Train available capacity adjustment · Inbound passenger flow limiting

1 Introductions

Current researches on passenger flow control in the field of traffic and transportation focused on passenger flow organization in stations and train operation management.

Some literature analyzed the characteristics of urban rail transit passengers and structural characters of the network and made measures of passenger flow control according to these findings. Qiaomei [1] researched on the characteristics of mass passenger flow, influence factors of station operation, and relative organization method. Lu [2] used complex network-based transmission dynamics model to develop the crowding propagation model of burst passenger flow, analyzed the propagation characteristics of passenger flow, and proposed measures to respond to the passenger flow.

Some researches proposed station organization principles to solve the problems of inbound and outbound passenger flow. Jianlin [3] studied the contradiction between passenger volume and transportation capacity in Line 6 and 8 of Shanghai Subway, and changed the stations to apply measures of passenger flow control

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according to principles of choosing control stations and time. Lianhua [4] analyzed the problems of increased passenger volume and complex transfers in Guangzhou Subway, calculated to obtain the control stations and volumes, and made relative passenger flow control strategies.

Some literature analyzed passenger flow regularity between two stations and made passenger flow control schemes. Yingsong [5] proposed a parameter calculation method based on priority for station coordination control, which provided a theoretical foundation for reasonable schemes of passenger flow control. Zheng [6] further put forward the idea of combined control in several subway stations.

Some researches adjusted train operation scheme to relieve the contradiction between passenger demand and line transportation capacity. Suh [7] applied stop-skipping service to Seoul subway in Korea and decided the stop-skipping stations by predicted OD. Sun [8] adopted nonlinear integer programming to realize the stop-skipping strategy in real-time operation. Cortés [9, 10] adopted the mixed strategy of holding and stop-skipping to control public traffic lines to reach the target of minimum waiting time and uniform headway.

This paper will combine two strategies of inbound passenger flow limiting and train available capacity adjustment to manage subway operation synthetically and improve the passenger flow conditions in peak hours.

2 Passenger Flow Control in Subway Stations

Passenger flow crowding results from real-time mismatching between train available capacity and passenger flow demand. So efforts should be made in two aspects: inbound passenger flow limiting and train available capacity adjustment.

(1) Inbound passenger flow limiting. In the condition of large passenger flow, the control strategy to limit passengers outside the station entrances can be made to slow down inbound passenger speed and control redundant passengers outside the subway system. In the demand peak hours, large passengers want to go inside the stations and get a train to start their trip in short time and thus overcrowding often occurs and decreases passenger inbound efficiency and volume. What's more, there may be potential danger and accidents in the special condition. Purposive and sequential passenger flow control can guarantee passenger safety and promote passenger inbound efficiency.

(2) Train available capacity adjustment. In the peak hours, trains usually run at the minimum headway in subway, which means that available transportation capacity for lines has reached the maximum, while passenger flow in crowded stations is still unsatisfied. Responding to this kind of situation, the strategy of train available capacity adjustment for different stations is practicable, which can be realized by the adjustment of train operation scheme. It can change the train stopping frequency at stations in the peak hours to reserve train available capacity for the stations with large passenger demand and thus relieve the pressure of the platform organization.

3 Algorithm Implementation

3.1 Improved Genetic Algorithm

In the application of genetic algorithm, researchers gradually found out that traditional methods had many shortcomings, which could not satisfy the need for solution in quality and speed. These shortcomings included: (1) there existed subjectivity and experience in coding of decision variables, fitness function, inheritance, and parameter setting; (2) evolution results depended on initial values of parameters and population to some extent; (3) inappropriate inheritance might lead to missing of population variability; (4) convergence speed decreased along with the increase of coding length of decision variables. To overcome these shortcomings, many improved genetic algorithms, incorporating improvement for coding way, heritance operators, control parameters, and operation strategies have been put forward.

The solving algorithm of this paper adopts improved genetic algorithm and the improvements include the adoption of order crossover in the process of individual crossover and the improvement of mutation sites in the process of individual mutation.

3.2 Algorithm Process of Passenger Flow Control

The improved genetic algorithm for passenger flow control in subway stations is implemented in the following steps:

Step 1: Set initial train operation scheme. Demarcate passenger parameters (passenger arrival rates in stations and alighting rates from trains), station parameters (inbound capacity and platform holding capacity), and train parameters (train capacity, train running and holding time standards). Set the population scale, maximum cycling times, crossover way, and mutation way for the algorithm.

Step 2: Realize the mutual constraints of passengers, stations, and trains. Mutual constraints of passengers and stations include passengers entering stations in the condition of inbound passenger flow limiting and passengers waiting for trains at platforms. Mutual constraints of trains and stations are expressed in the process of passengers boarding and alighting from trains. Constraints of trains incorporate train capacity, holding time, and running time.

Step 3: Output current train operation scheme and inbound passenger flow limiting results and calculate the fitness function, which pursues the maximum boarding passenger number and minimum variance for boarding ratios. If the current solution is better than the existing solution, use the current solution to update the existing solution. Otherwise, keep the existing solution unchanged. Update i with $(i + 1)$, and enter the next step.

Step 4: Judge if the cycling times have reached its maximum limit I. If it is, the final train operation scheme, passenger flow limiting solution, and objective function values will be output. Otherwise, enter the processes of heritance, crossover, and mutation and produce the next generation. Heritance refers to keeping some of the routings in the current train operation schemes, crossover means to mix some routings and get a new generation and mutation is to choose and mix two routings stochastically in unexplored schemes to get a new generation. Then enter the next step.

Step 5: Begin a new scheme algorithm calculation and enter Step 2.

When the cycling of the above steps ends, the algorithm ends and the optimal scheme and control results will be given as output. The flowchart is shown in Fig. 1.

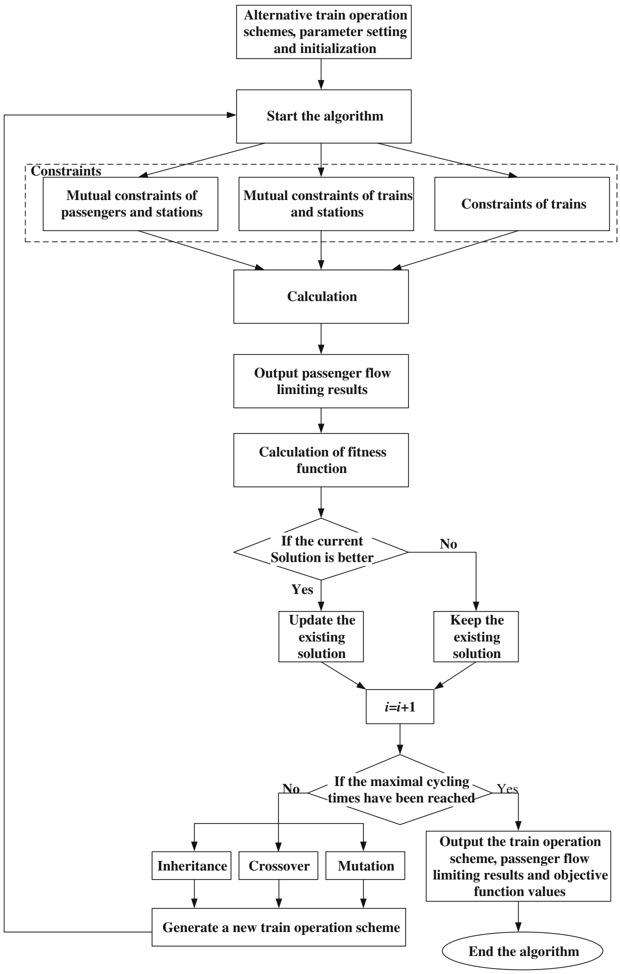

Fig. 1 Algorithm flow chart for passenger flow control in subway stations

The above algorithm depends on the platform of Visual Studio with the help of the programming language C#. Its interface of parameter setting and running results is shown in Fig. 2. Based on different solving efficiency and quality, population scale and cycling times can be set manually. For the process of crossover in genetic algorithm, crossover way and sites can be chosen freely. As to mutation, its probability can be changed to ensure the variability of solving effects. In all, improved genetic algorithm can facilitate summarizing the rules of solutions and finding the optimal solution rapidly.

4 Case Study

4.1 Parameter Setting

The case study chose a section in Line 3 of Guangzhou Subway, where stations locate as Lijiao (LJ), Datang (DT), Kecun (KC), Guangzhouta (GZ), Zhujiangxincheng (ZJ), and Tiyuxilu (TY) in the down direction. Passenger flow demand in each station in the morning peak hour is listed in Table 1.

Holding time of trains at each station, running time of trains on each section, arrival rates, and alighting rates of passengers are shown in Table 2.

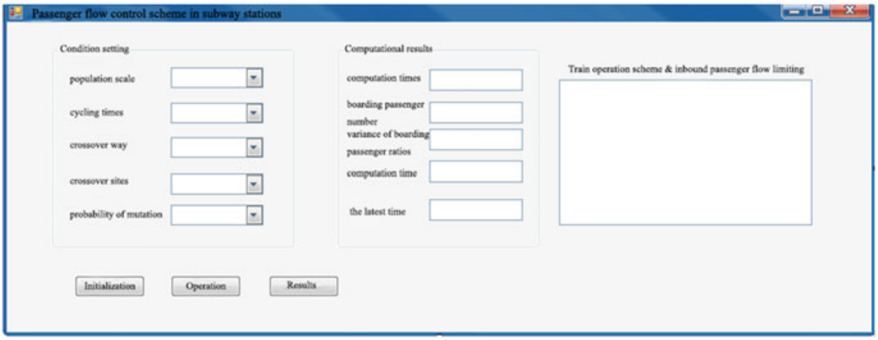

Fig. 2 System interface of condition setting and results

Table 1 Passenger flow demand in each station

Station	Passenger flow volume	Sequence
LJ	19,200	6
DT	23,400	5
KC	65,850	3
GZ	30,930	4
ZJ	70,740	1
TY	68,670	2

Table 2 Basic data of trains and passengers

Station		LJ	DT	KC	GZ	ZJ	TY
Train	Holding time (min)	0.5	0.5	1	0.5	1	1
	Running time to the next station (min)	2.5	2	1.5	2	2	
Passenger	Arrival rates (persons/min)	320	370	637	205	645	649
	Alighting rates (%)		6.3	68.8	3.7	72.2	58.3

Train headway is 2 min in the peak hour. Train capacity standard is 1350 persons. When the passengers are overcrowded, the maximal train capacity is 1882 persons.

4.2 Solving Results and Analysis

These parameters and initial settings are input to the solving algorithm system. The optimal train operation scheme is shown in Table 3.

Table 3 The optimal train operation scheme

Train NO.	Train operation scheme
1	LJ-KC-ZJ-TY
2	LJ-KC-ZJ-TY
3	LJ-DT-KC-GZ-ZJ-TY
4	LJ-KC-ZJ-TY
5	KC-ZJ-TY
6	LJ-DT-KC-GZ-ZJ-TY
7	LJ-DT-KC-GZ-ZJ-TY
8	LJ-DT-KC-GZ-ZJ-TY
9	KC-GZ-ZJ-TY
10	LJ-KC-ZJ-TY
11	KC-GZ-ZJ-TY
12	LJ-KC-ZJ-TY
13	KC-ZJ-TY
14	KC-GZ-ZJ-TY
15	KC-GZ-ZJ-TY
16	KC-GZ-ZJ-TY
17	KC-ZJ-TY
18	KC-GZ-ZJ-TY
19	LJ-KC-ZJ-TY
20	LJ-DT-KC-GZ-ZJ-TY
21	LJ-DT-KC-GZ-ZJ-TY
22	LJ-DT-KC-GZ-ZJ-TY
23	LJ-DT-KC-GZ-ZJ-TY

Table 4 Inbound passenger flow limiting schemes in each station

Station	Passengers limited in the peak hour (persons)	Average passenger flow speed after control (persons/min)
LJ	4386	73
DT	3775	63
KC	5605	93
GZ	3893	64
ZJ	5986	100
TY	5230	87

In this scheme, all boarding passengers are up to 51,525 persons on the line in the peak hour and the variance of boarding ratios at each station is 0.03. The control scheme of passenger flow is shown in Table 4. In the peak hour of passenger flow, limiting volume and speed at each station can be determined and thus control strategies are made coordinately to realize the objectives of the maximal boarding passengers and balanced inbound service.

5 Concluding Remarks

In this paper, two kinds of strategies, which are train available capacity adjustment and inbound passenger flow limiting, are analyzed to optimize the organization of large passenger flow in subway stations. To make detailed strategies in certain passenger flow condition in an efficient and high-quality way, improved genetic algorithm is utilized to solve the problem. An application case of line 3 in Guangzhou Subway is studied to verify the validity of the algorithm. In the future, the algorithm will be applied to more practical cases and thus relative modification can be made to promote the algorithm solving process.

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