

Determination of stations where rapid trains stop, or pass to local ones, using a genetic algorithm to shorten total trip time

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Abstract

This research is focussed on shortening the total trip time for passengers with the operation of rapid trains and is included in the improvement of the train diagram. To this aim, the combination of the stations where rapid trains stop, or pass to local ones, needs to be properly set. However, a best solution is not calculated in real computational time using a round robin method, because there are complex relationships between the OD (origin and destination), combination of stations and operational effects of the trains.

In this paper, we describe a solution to the problem using a genetic algorithm (GA). We determined that the operation of the trains at a station can be classified by the following four conditions:

- Rapid trains stop or pass
- Rapid trains pass, or do not pass, to local trains

These result in a difference of train diagrams at the station. A gene-code in GA expresses these four classified codes. A chromosome consisting of these chain codes denotes a train diagram on an applied line. The length of a chromosome is the number of stations on the line.

Whereas, the resulting combination of the stations is a near best solution, it may not be perfect. However, it is shown that the possibility of a shorter total trip time is approximately 11[%] compared with the time of a real train diagram pattern for a real subway line in Tokyo. The reason for this is considered to be a result of the random effects of the GA.

Keywords: rapid train, total trip time, train diagram, combinatorial problem, genetic algorithm.



1 Introduction

This research is focussed on shortening the total trip time for passengers on railway transport using rapid train operation (Katori et al. [1]).

There are two ways to shorten total trip time (Iguchi [2]). One is via the hardware, which includes improvement of both the driving performance and infrastructure on the ground. The other approach is via software, which relies on improvement of the train diagram. This research focuses on the software approach because it does not require investment in new equipment and infrastructure.

To shorten the time using rapid train operation, rapid train stopping stations need to be properly situated in order to improve convenience in a railway line. Stations where rapid trains pass forward to local ones are also considered important and are to be included on the train diagram.

The combinations of the stations exist in huge numbers, and therefore it is not possible to solve used round robin method on real computational time. Or there is a case that the calculated optimum solution is for local train operation only.

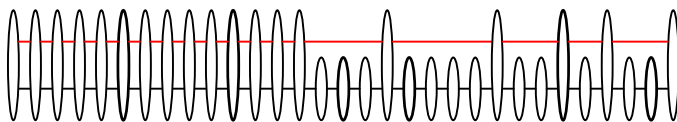


Figure 1: The concept figure of this study.

In this paper, we describe a method to determine proper stations that rapid trains stop at, or pass to local ones, using a genetic algorithm (GA) to shorten total trip time considering to realize train diagram. The gene-code in the GA denotes the state of a trains operation at a station, and a population that connects these codes means a train diagram for an applied railway line.

The combination of the stations that is determined via this method for the subway line in Tokyo has shown a possible solution that has an approximately 11[%] reduction in the trip time compared to the real pattern of train operation.

2 Condition for rapid trains operation

2.1 Input data

A method to determine the stations using the GA is described in this section. Input data to the algorithm are the OD (origin and destination) table and condition of the applied railway line.

In the OD table, passenger numbers are expressed in matrix form. The condition of the railway line is composed of requisite running time between each station and location of passing equipment for the applied line.

(2) Evaluation value

Evaluation value is total trip time, because the aim of this research is to shorten the total trip time.

The evaluation value is shown in equation (1) as follows:

$$\text{Evaluation value (total trip time)} = \sum_t \sum_{i,j} \text{EOD}(i,j,t) * \text{rt}(i,j,t) \quad (1)$$

$\text{OD}(i,j,t)$: number of passengers from station No.i to No.j at time t.

$\text{rt}(i,j,t)$: required moving time from station No.i to No.j at time t.

This moving time includes running and waiting time at origin station.

Equation (1) means total trip time considering the train diagram in the applied line. This evaluation value is calculated via the following procedure: multiply required time by passenger numbers from one station to another at a single moment, considering all combinations between all origin stations and destination ones in all moments. If passenger numbers are the same, then a smaller evaluation value means a shorter total trip time as a useful effect of rapid train operation.

2.2 Assumptions in rapid trains operation

- The kinds of trains are rapid and local only. The stations where rapid trains stop, or pass to local ones, are static.
- The train diagram repeats the same pattern every departure cycle.
- The applied line has a double track, and rapid trains can pass to local trains at the station only.

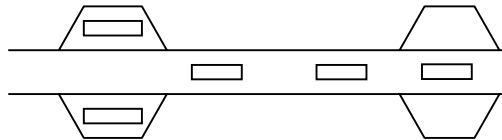


Figure 2: The concept of the equipment at the stations.

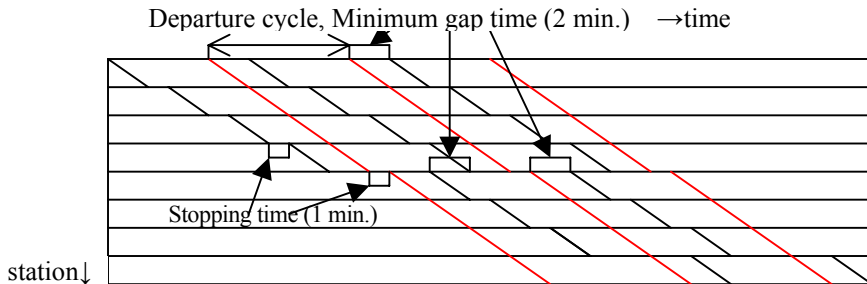


Figure 3: A sample train diagram to explain the conditions.

- All trains reach the terminal station. There are no trains that turn on part of the line. Minimum gap time on the diagram is two minutes, and stopping time of the trains is greater than, or equal to 1 minute. Rapid trains can shorten stopping time at the stations, but cannot shorten running time between stations.
- For all passengers, rapid trains do not need a special fare to ride, i.e. there is no tradeoff between cost and time.
- All passengers who can shorten their trip time change trains at the station on the line.
- Operation trains have the same driving performance.

3 Determining the station where rapid trains stop or pass to local ones using a GA

The genetic algorithm is a useful algorithm that models the process of evolution and searches the solution of the combinatorial problem on the machine.

When applying the algorithm, it is difficult to synchronize the elements of the algorithm due to the following problems:

- What does a gene express?
- What is fitness as an evaluation value?

In the proposed method, a gene-code expresses the previously classified statement of train operation at a station, and a chromosome that connects the codes expresses the train diagram. The evaluation value is the total trip time shown in equation (1).

3.1 Expression of gene and chromosome

At any given station, there are four combinations of statements for rapid and local train operation using the following two conditions:

- Rapid trains stop or not stop
- Rapid trains pass, or do not pass, to local trains

These classifications are shown in Table 1, and correspond to the gene-codes. Figure 4 shows the relation of these gene-codes to the train diagram in Figure 4.

A line connected the codes is a chromosome, that means train diagram on applied line, and the length of the line is number of the stations on the line.

Table 1: Expression the gene code at the station.

Gene Code	Stopping of Rapid Trains	Rapid Train Pass to Local Train
0	Not here	Not here
1	Here	Not here
2	Here	Here
3	Not here	Here



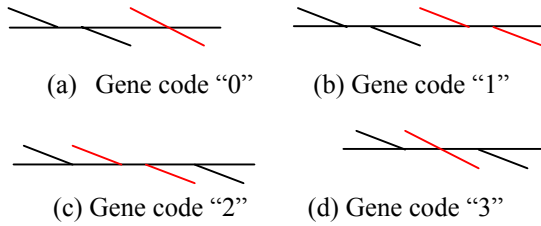


Figure 4: Relation of gene code to train diagram.

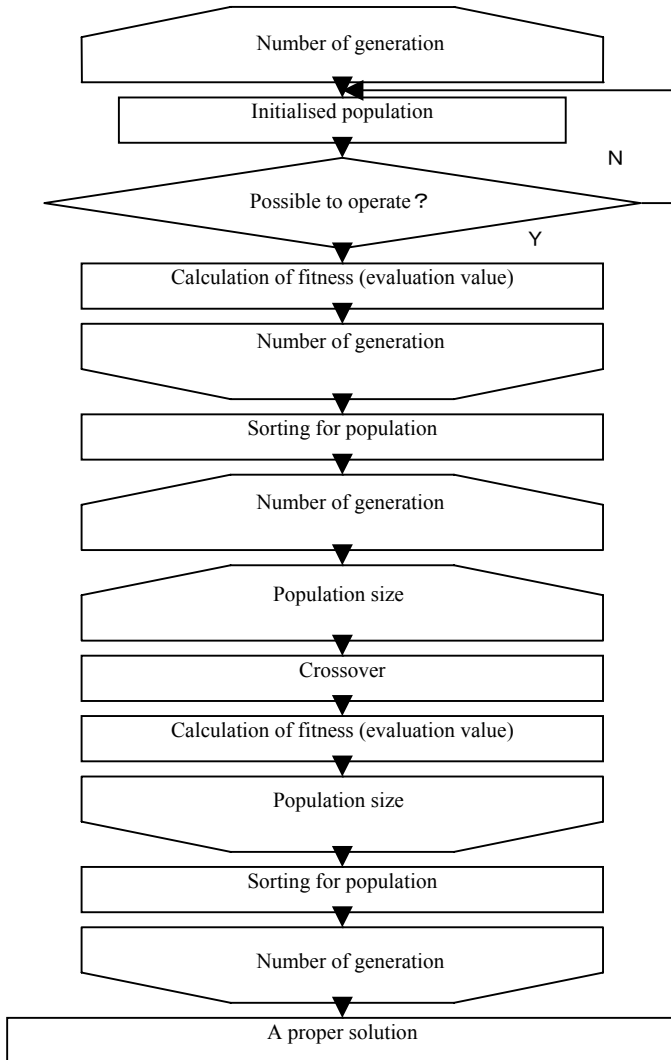


Figure 5: Flowchart to determine the stations used genetic algorithm.



3.2 An example to determine the stations used GA

Figure 5 shows the procedure to determine the stations where rapid trains stop, or pass to local ones, using the GA. The process of mutation (evolutionary) in the general GA is not incorporated into the proposed method.

An example of determining the stations is shown in the following:

On a sample line with 11 stations, populations are initialised based on codes in Table 1; "20003001301", "20103100311" and so on. These populations are expressed in Figure 6 (a)(b).

Crossover, in this procedure, means changing train diagrams at the station where rapid trains pass to a local one. Therefore, the crossover points are the stations where the trains pass to the local one. Populations that have the same gene-codes at the crossover points are able to crossover to each other. The sample train diagrams in Figure 6 (a)(b) are able to crossover at stations No. 4 and No. 8, because the rapid trains pass to local ones at these two stations. Figure 6 (c)(d) shows results of train diagrams after crossover at station No. 4.

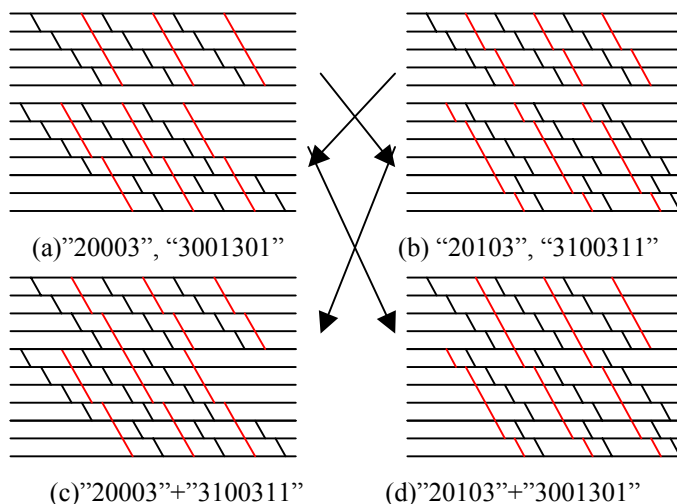


Figure 6: Crossover for the train diagrams.

All of the populations that these parents and generated after crossover are train diagrams that can operate trains. These train diagrams are expressed as graph data (Katori et al. [1]). A shortest time path that passengers transfer the trains to arrive earliest at their destinations between their origin station No.i at they appearing and destination station No.j is searched by graph algorithm (Katori et al. [1]). Fitness as evaluation value of the total trip time is calculated by equation (1) using the OD matrix. Populations that have high fitness are able to continue into the next generation.

These procedures are repeated while setting generation times, after the procedure, a chromosome that has highest fitness is a near best solution of a train diagram of the stations.

4 Case study and consideration

4.1 Applied line

The applied line is the subway TOZAI line through to the TOYO rapid line in Tokyo, Japan. Figure 7 and Table 2 show the condition and equipment on the line. Passenger numbers in the OD matrix have been sourced from [3].

Parameters in the GA set 256 populations and 16 generations. The proper solution adopted has a minimum evaluation value 15 times, because the random GA calculates a different solution after each process.

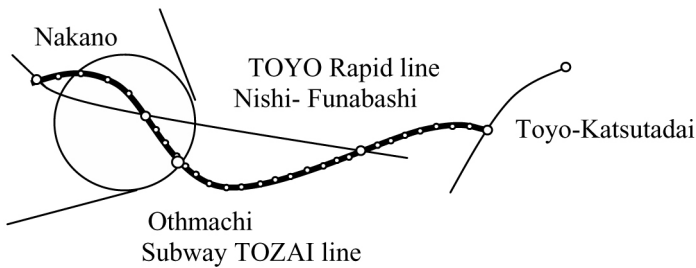


Figure 7: An applied line (Subway TOZAI line - TOYO Rapid line).

Table 2: The conditions of the applied line.

Length of applied line	47[km]
Number of stations	31
Number of passing equipment	7 stations

On the applied line, the effects of the rapid trains operation are compared with the following two conditions:

(A) The number of rapid trains and local one are equal or unequal.

This condition means that a local train has passed a rapid train only once or a few times. These differences are shown in the train diagram in Figure 8.

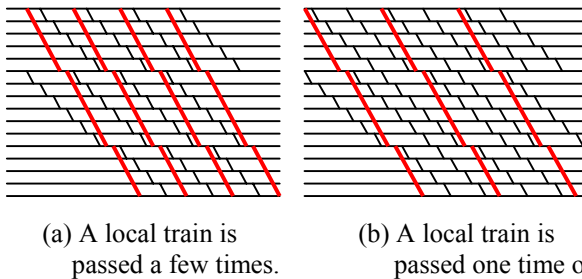


Figure 8: Difference from train diagrams at same passing station.

(B) Passing lines exist all stations or real equipment only.
 Result of four ($=2^2$) evaluation values by two conditions are shown in Table 3.
 The number of trains in a unit time are operated the same as in the real train diagram, because if many trains are operated on the applied line, the effect on the trains is expected to be a high transport performance. The standard evaluation value is set to the real train diagram. To compare the evaluation, the rate for standard evaluation value is used to improve the rate of the total trip time.

Table 3: Proper solutions of combination under any conditions.

No.	Departure cycle time [min]	Ratio of rapid and local	Passing equipment stations	Improved rate of total trip time	Used DP ^[1]
1	10	1:1	All	0.95	0.96
2	10	1:1	Real	0.95	0.97
3	45	1:8	All	0.89	0.92
4	15	1:2	Real	0.97	0.99

(1) Characteristic of each evaluation value.
 For the applied line, it is shown that total trip times are capable of being shortened by rapid trains for all cases. If the stations are properly set, it is possible to reduce the total trip time by approximately 11% (No.3), under real conditions is approximately 5% (No.2). Effects to shorten have dispersed under each case; in case No.3, where the density of passing equipment has no limit, the effect is highest. This fact suggests that the density of the passing equipment is important under condition (B), it means that density of the real one is not proper.

Figure 9 shows a combination of the stations where rapid trains stop or pass to local one in case No.3. Bold ellipses are stations of passing to local train. Figure 10 shows the train diagram in this case. In Figure 10, a rapid train passes to eight local trains.

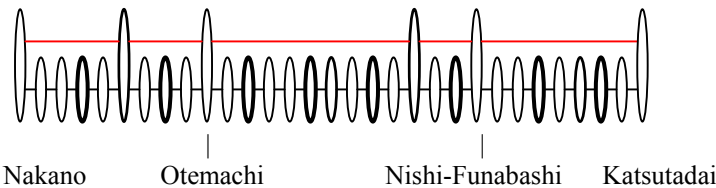


Figure 9: An example of determination of the stations (No.3 in table 3).

(2) For using genetic algorithm
 Improved rates of total trip time have shown that results using the GA method are a little shorter than when using the DP method (Katori et al [1]). The reasons for this are considered to be that it is difficult to extract relation rules versus input condition, and random elements in GA causes useful effects for this problem.

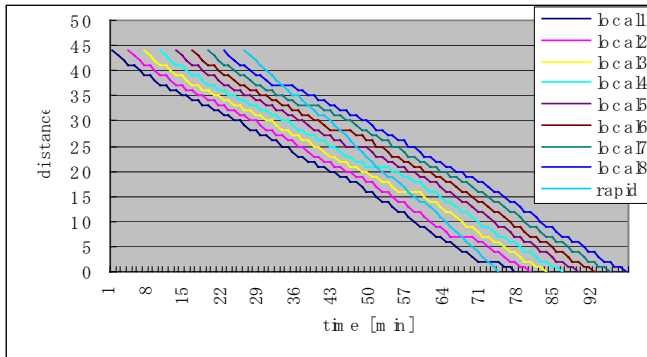


Figure 10: An example of train diagram for the operation Figure 9.

5 Conclusion

In this paper, we have described how to determine the proper stations applied genetic algorithm that rapid trains stop, or pass to local ones, to shorten total trip time for passengers. In the proposed method, a gene-code is the operation statement of the rapid and local trains at a station, these chain codes express the train diagram in a line. Crossover in the GA denotes the changing connection of the train diagrams with each other at the station where rapid trains pass to local ones.

This method applies to the real subway line in Tokyo, in near best solutions, approximately 11% shorter total trip time, under maximum possible conditions, was shown compared with the operational pattern of the real train diagram.

In the future, more complex operation patterns of the trains and arrangements of crossover points discovered via GA will be considered, because quality of solutions depend on the points, and so on.

References

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