Research on Public Traffic Vehicles Dispatch Based on Improved Adaptive Genetic Algorithm

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Abstract—Bus dispatching has been studied, and also the bus dispatching model is set up. Then, Genetic Algorithm is adaptively improved in order to avoid premature problem and the slow convergence, and then the keeping optimal strategy is used to the Genetic Algorithm, so formed the Improved Adaptive Genetic Algorithm, namely IAGA. Finally, the IAGA is used to optimizing the bus dispatching model, and the results of the simulation indicate IAGA has the higher efficiency than simple GA and is one effective way to optimizing the bus dispatching.

Keywords—urban public transport; bus dispatching; genetic algorithms; adaptive genetic algorithm

1 Introduction

With the rapid development of the world urbanization process, urban traffic congestion, road block, frequent accidents, and environmental pollution are becoming increasingly serious. Developing urban public transport and promoting public transport priority is an effective way to solve the problems of urban transport. Bus scheduling is an important aspect of public transport, and therefore carrying out a reasonable schedule management on public transport is particularly important [1]. About the bus scheduling problem it is necessary to consider the waiting time of passengers and the benefits of public transportation company, so is a combinatorial optimization problem. In order to solve the problem, there is a necessary to use intelligent optimal algorithm on bus scheduling.

At present, there are several common intelligent algorithms, such as Genetic Algorithm, taboo search algorithm, simulated annealing algorithm, neural networks, and so on. Compared with other optimal algorithms, GA has inherently implicit parallel property and better ability of global optimization. In the article the genetic algorithm is used to the public transport scheduling. As the standard genetic algorithm demonstrates the slow evolution and early convergence in practical applications, we use the adaptive method to choose the crossover and selection probability, at the same time, the keeping priority strategy is applied, so the improved adaptive genetic algorithm is got, namely IAGA. And then IAGA is applied to optimize public transport scheduling.

2 Improved Adaptive Genetic Algorithm

2.1 Genetic Algorithm

Genetic Algorithm is a simulation of an adaptive search algorithm for global optimization which was formed in the heredity of natural environment and the evolutionary processes. It was a new global optimization algorithm which was first proposed by Professor Holland of the United States in 1975 [2]. Genetic algorithm is an algorithm based on natural selection principles and genetic search algorithm. It introduces the basic evolutionary theory of survival of the fittest to the bunch structure, and the fine genetic is gradually retained and combined with the algorithm running, so as to continuously produce better individuals. An individual of a new generation is better than father's generation in overall performance, so that the group as a whole forward develops. Compared with the traditional optimization method, genetic algorithm has the differences:

1) The objects dealt directly by the genetic algorithm are the coding collection of the decision variables rather than the actual value of the decision-making variables. It is not need to endure the continuous constraints from the optimization function, and is not has the requirements of the existence of optimization function derivative.

2) Genetic algorithm uses multi-point searching method, which has a high implicit parallelism.

3) Genetic algorithm uses the method of probability optimization, it can access automatically an
guide the optimal search space and adaptively adjust the search direction. It is not need to determine the rules, thereby increase the flexibility of the search process and has the large probability of convergence to the optimal solution, with better ability to solve global optimization.

However, due to the genetic algorithm use the selection mechanism which decides whether the individual be copied base on the size of fitness value. It is prone to such individuals from the same population by a large number of reproductions, so resulting in the local search and the premature convergence, finally the failure of global optimization process, especially for multi-peak function prone to this phenomenon.

### 2.2 Adaptive Genetic Algorithm

The parameters of genetic algorithm such as crossover and mutation probability directly impact on the choice of the convergence nature of algorithm, the bigger the crossover probability is, the faster the new entity comes into being. However, if the crossover probability is too large the damage possibility of genetic model is also greater, so make the individual structures of high fitness are destroyed very soon. However, if the crossover probability is too small, it will slow the search process, even stagnate. For mutation probability, if it is too small, it is not easy to generate new individual structure, and if too large, the genetic algorithm will become a purely random search algorithm.

In order to solve these problems, Srinivas brought forward to Adaptive Genetic Algorithm in 1994[3], so that Pc and Pm automatically change with the fitness. When the fitness of the individual is go consistent or get local optimum, increasing Pc and Pm. When the fitness of the group are dispersed, reducing Pc and Pm. Adaptive Genetic Algorithm not only maintains the population diversity, but also guarantees the convergence of genetic algorithm.

However, when the fitness is closer to the maximum fitness, Pc and Pm are smaller, and when the fitness is equal to the maximum fitness, Pc and Pm are zero. The adaptive algorithm is more appropriate for anaphase, but disadvantage for the initial stages of the algorithm, because it is easily increase the likelihood of making the evolution to the local optimal solution. In view of this situation, the adaptive algorithm are improved, the calculations expression of Pc and Pm are as follow s[4]:

\[
P_c = \begin{cases} 
\frac{(p_{c1} - p_{c2})(f - f_{avg})}{f_{max} - f_{avg}} & f \geq f_{avg} \\
p_{c1} & f < f_{avg} 
\end{cases} 
\]

\[
P_m = \begin{cases} 
\frac{(p_{m1} - p_{m2})(f_{max} - f)}{f_{max} - f_{avg}} & f \geq f_{avg} \\
p_{m1} & f < f_{avg} 
\end{cases} 
\]

Where Pc1 is 0.9, Pc2 is 0.6, Pm1 is 0.1, and Pm2 is 0.001 normally.

### 2.3 Improved Adaptive Genetic Algorithm

In the running process of Adaptive Genetic Algorithm, it continuously produces new individuals through the operation of crossover and mutation. Although along with the evolutionary process the groups will have an increasing number of excellent individuals, but because of random of genetic operation, such as selection, crossover and mutation, they may also destroy the best individual fitness in the current group. This is not what we hoped, because it reduces the average fitnesses of groups, as well as has adverse impacts on the efficiency of genetic algorithm and convergence [5]. Therefore, we hope that the individual of best fitness as much as possible is retained to the next group. To this aim, we use the optimal preservation strategy evolutionary model to the operation of the survival of the fittest, the adaptive genetic algorithm is improved, that is, the individual of current optimal fitness in groups is not involved in the cross operation and mutation operation, but is used to replace the individual of the worst fitness in groups of this generation through genetic operations. Specific operations are as follows:

1. Finding out the individual of minimum current group, that is the current best individual labeled as fitmin.
2. Getting new groups after cross and mutation operations, finding the maximum fitness in the new group, that is the worst individual labeled as fitmax;
3. If fitmax is bigger than fitmin, then fitmin replaces fitmax, or else new groups remain unchanged.

Optimal strategy can guarantee the best individual of the present will not be destroyed by cross over and mutation operations, it is an important guarantee condition of the convergence of genetic algorithms.

The main steps of IAGA are as follows:

1. Initializing the control parameters and determining the population size n.
(2) Initializing the population, randomly generate n feasible solutions $x_i (1 \leq i \leq n)$, and form the initial population $p$.

(3) Evaluate fitness of all individuals in $p$.

(4) Adaptive operation, calculate the crossover probability and carry through crossover operation.

(5) Adaptive operation, calculate the mutation probability and carry through mutation operation.

(6) If meet the convergence conditions, achieving to the pre-set largest evolution number $m$, then exit the process, otherwise return to step (3).

3 Foundation of bus scheduling model

Bus scheduling is necessary to consider not only the interests of the company but also the interests of passengers, and the interest of passengers is the cost of waiting time at the station, the interest of the company is operating cost. In this paper, we set up the bus scheduling model based on the smallest passenger cost and operating cost of company.

3.1 The passenger cost

Passenger cost is related to passengers’ waiting time at stations, which are the adding of each passenger’s waiting time at each station, then the whole day passengers’ waiting time on the line of all stations are:

$$T_{pw} = \sum_{k} \sum_{m} \int_{t_{ak,m}}^{t_{ak,m-1}} P_{ak}(t) \times (t_{ak,m} - t) dt$$

Where:

- $k$—Station ($k=1,2,3,...$)
- $t$—Continuous-time in the scheduling Cycle ($t=1, 2, 3...T$, $T$ is scheduling Cycle)
- $m$—Vehicle ($m=1,2,3,...$)
- $P_{ak}$—Passengers’ arrival rate of station $k$
- $t_{ak,m}$—The time of bus $m$ reaching the station $k$
- $t_{ak,m-1}$—The time of bus $m-1$ reaching the station $k$

So the passenger cost is:

$$E_{pw} = r_{pw} \times T_{pw} = r_{pw} \sum_{k} \sum_{m} \int_{t_{ak,m}}^{t_{ak,m-1}} P_{ak}(t) \times (t_{ak,m} - t) dt$$

(4) Where:

- $r_{pw}$—The conversion factors which translate passengers’ waiting time into passengers’ travel cost (Yuan/minute)

3.2 The bus company operating cost

The company cost is denoted by all bus trips costs, that is:

$$E_{cw} = r_{a} N$$

Where:

- $r_{a}$—Cost of Bus travel one time (Yuan / vehicle trips)
- $N$—The number of departing bus

3.3 Total costs of Passenger and the company

Total costs of Passenger and the company are the sum of passenger and company costs, and so the bus optimal scheduling model is established as follows:

$$E = r_{pw} \sum_{k} \sum_{m} \int_{t_{ak,m}}^{t_{ak,m-1}} P_{ak}(t) \times (t_{ak,m} - t) dt + r_{a} N \quad (6)$$

Bus scheduling problem belongs to the optimal problem of getting the minimum value of objective function, so the conversion must be carried out and conversed formula is:

$$F(X) = C_{max} - f(X) \quad (7)$$

Where:

- $C_{max}$—The maximum of all the objective function in a generation group.

It can be seen that based on genetic algorithm the fitness derived from the formula is greater or equal to zero, and also the smaller the objective function value, the greater the individual's fitness.

4 Algorithmic design

In this paper, one bus line in a city is studied and the bus departure schedule in up direction is optimized. There are 13 stations of the line in the direction. The first bus departure time is at 5:00 AM and the last one is 11:00 PM. All of buses start on time. The number of passengers throughout the day has been known which is shown in Figure 1. The objective is to calculate the departure schedule for the day and must meet the maximum needs of passengers and reduce travel costs.

![Figure 1: Passenger arrival rate of the line](image)
divide the day into several equal time, such as the morning peak and evening peak, etc., and every period has the same interval. Based on the actual situation, according to Fisher algorithm, optimize the flow of the passengers and get the five categories of the optimal division of the bus line which is shown in table 1.

<table>
<thead>
<tr>
<th>Periods of time</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:00</td>
<td>6:00</td>
<td>9:00</td>
<td>16:00</td>
<td>18:00</td>
<td>23:00</td>
</tr>
</tbody>
</table>

According to the above analysis, we take the departure interval as decision-making variable, it is \( h_1, h_2, h_3, h_4, h_5 \) and \( h_i \in \{ H_d, H_e \} \), \( i = 1, 2, 3, 4, 5 \), where \( H_d = 2, H_e = 30 \) in the paper.

4.2 Coding and population initialization

The coding method is decimal system, so the chromosome is the string of real headway value, namely \{ h1, h2, h3, h4, h5 \}.

Population initialization is to initialize the chromosome randomly which composes the population, and the chromosome must be met with the required first and last departure time.

4.3 The design of genetic operator

GA operators include choice, crossover and mutation operator, and they are applied to the group \( P(t) \) successively, then the new generation group \( P(t+1) \) is produced.

(1) selection operator

This paper the fitness proportional model is adopted, which is known as Monte Carlo selection.

We assume that Population size is \( n \), the fitness value of individual \( X_i \) is \( f(X_i) \) \( (1 \leq i \leq n) \), then the selection probability is selected is:

\[
G_i = \frac{f(X_i)}{\sum_{i=1}^{n} f(X_i)}
\]

(2) crossover and mutation operator

We choose one point crossover and manipulation uniform mutation in the algorithm.

5 Simulation and analysis of results

We assume population size is 50, crossover probability \( P_c \) and mutation probability \( P_m \) is obtained by adaptive Genetic Algorithm, and the generation number \( m \) is 100.

Figure 2 shows the convergence process of Genetic Algorithm (GA) and Improved Adaptive Genetic Algorithm (IAGA), and Figure 3 show bus depart frequencies of one hour in GA and IAGA respectively.

![Figure 2](image2.png) The convergence of IAGA and GA

![Figure 3](image3.png) The whole day bus frequencies

We can see that the convergence of IAGA has been greatly enhanced which compare to GA from figure 2. We also see the results from IAGA more meet actual distribution of passenger flow (figure 1) from figure 3, in which the bus departure frequency correspond to the morning and evening traffic peak hours and reflect the interests of passengers. Further more the results illustrate the IAGA has more better efficiency, also explain that the bus scheduling model established reflects the actual situation and is feasible.

6 Conclusion

The task of bus transport operation is to manage effectively and allocate the limited vehicle resources rationally, also adjust the supply and demand balance to achieve the best objectives. This paper improved the genetic algorithm about its slow evolution and early convergence, let genetic algorithm has adaptive ability. The results show that the improved adaptive genetic algorithm can find approximate optimal solution in the huge search space with a reliable way and is better than the standard genetic algorithm.

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