The Bus Auxiliary Driving System Based on Multi-Agent Strategy

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Abstract: Bus bunching reflects the bus schedule instability. With the lack of communication and passengers' increasing demand for traffic, bus bunching will cause greater damage in public transport system. Therefore, based on the multi-agent system of high robustness and reliability, we present the distributed scheduling strategy in order to improve the scheduling efficiency and enhance the reliability of public transport system and build the software of bus auxiliary driving system. Furthermore, combined with the actual bus operation, an algorithm is evaluated on the basis of theoretical research feasible algorithm. The results show that this agent scheduling policy is an effective way to enhance the bus operation reliability and promote the efficiency of public transport system.

Key words: Software of bus auxiliary driving system, bus bunching, Mutil-agent, distributed scheduling strategy.

1. Introduction

In highly populated urban zones, it is common to notice that passengers waiting at a bus station for a long time do not wait for a bus, and once the bus coming, it's successive two or three vehicles. This phenomenon is known as "bus bunching". There is no bus lanes for general buses, and the urban road congestion, severe interference of intersection, and interference after adjustment is not timely, accurate, can't meet the needs of punctuality, bus operation reliability problems become the key factor of service quality .From the perspective of the bus company, decreasing reliability leads to the loss of passengers, reducing its earnings; For the passengers, "bus bunching" affects their travel comfort and increases the cost of travel time; From the perspective of the whole society, bus riding sex is destroyed and the software of bus auxiliary driving system needs to be build.

Therefore, the task is to force adherence to the schedule. Improve the reliability of the traditional way is to let every car will be effected according to the established managers and decision makers in doubt. schedules to each site on a line, if there is a solution that can make bus on time, so operation of the fleet size must be in the optimal state. But in reality, it's very difficult to achieve it. In addition, according to Lin, and so on to complete the federal public transport authority "public traffic adaptive control" [1], under the condition of highly populated urban zones and high departure frequency, it is more important the headway regularity than the fulfillment of the arrival time at the bus stops. Therefore, this article developed the a driving system of algorithm robustness, the controllers can take actions like holding strategy in order to avoid this headway instability, forcing the adherence to the schedule.

2. Literature Review

2.1. Bus Scheduling Based on Schedule

Scheele [2] put forward bus frequency as the decision variable, an optimization model is proposed to minimize passengers' travel time, and consider the vehicle capacity and transit assignment problem; Furth and Wilson [3] considered passengers' waiting time and the number of passengers to optimize the line of departure intervals, but do not take into account both sides of supply and demand interaction. In the last ten years, we focus on the trend from transfer synchronization, collaborative grid to determine the departure time, departure frequency. Zhigang Liu [4] studied on the collaborative optimization of regional operations scheduling system and the three links of schedules establishment, bus scheduling and the bus crew scheduling, also analyzed the collaborative systematic thought. These documents are from the aspects of regional dispatching of analyzing the optimization plans to operate or a plurality of modules, but models assume running time invariant. Based on reliability study, he analyzed the influencing factors of the public transportation system reliability and its composition, from the angle adjusting bus timetables to improve reliability of bus system and system of three Depending on the degree as the constraint conditions, the design schedule optimization model is constructed, and the departure interval of is determined [5].

2.2. Based on the Headway of Bus Scheduling

Because of its own limitations of establishment of timetable, for urban public transportation system, the best way to set timetable is to optimize the bus frequency, called control method based on the headway. For suburban bus, because the frequency is low and the long distance between bus station, so its requirements for bus punctuality is still high. This situation can be used in the traditional timetable scheduling method. Adamski [6] put forward public traffic dispatching control model, analyzing the process of vehicle running by the mechanism of running deviation; Turnquist [7] studied how to select from more than one control point to let all vehicles run at a uniform speed control strategy ;Bowman and Turnquist [8] considered passenger waiting time will make travel costs rise and can reduce the possibility of choosing public transport, the result is: waiting time at the station is more important than the bus service frequency effect on the reliability of the time .Huang hua [9] studied optimization control strategy based on the minimum deviation of planning schedule and actual arrive time.

2.3. A Distributed Scheduling Based on Multi-agent System

Chaib – Dra [10] analyzed the advantages of multi-agent systems for distributed computing, using multi-agent system to solve the problem of practical application, it has strong robustness and reliability and higher efficiency of problem solving. Multi-agent technology has broken the current limitation in the field of engineering, using only an expert to solve complex system task. When multi-agent technology is applied in the actual system, it can express the structure, function and behavior characteristics of the system through the communication between agents, cooperation, mutual understanding, coordination, dispatch, management and control. At present, multi-agent system has a tentative application in the intelligent robot, flight control, intersection traffic control, railway control, flexible manufacturing, coordinate, distributed prediction, monitoring and diagnosis, distributed intelligence decision-making, and other fields.

This paper introduces the concept of agent to the bus schedule, using a distributed computing instead of the traditional centralized computing of dispatching center to reduce the amount of calculation of each individual and enhance the overall efficiency.

3. Methodology

3.1. The Ideas of Multi-agent Systems

The traditional bus scheduling is based on control center. However, dispatch center depends on the powerful servers and precision of the algorithm to master the global transport system. So, it is difficult to give full play to the role of the bus. And the complexity of the control center leads to its high maintenance cost, once the dispatch center breaking down, it will cause the collapse of the whole system, this means that system robustness is not strong. On the other hand, this article found if we give full play to the role of each individual in real life, it can achieve high efficiency tending to the optimal result. This is how the concept of agent arises at the historic moment, agent need care about the surrounding controllable conditions, agent can let the system tend to the optimum state, and thus the required amount of calculation is reduced to a low state. In addition, when one of these agents malfunctioned, it does not affect the rest of the agents' work and will soon return to normal operation team, that is to say, agent system has strong robustness.

3.2. The Ideas of Multi-agent Systems

s_0 : Unit of road length,

$v_{\max}$: Road speed limit,

v_t : Current speed,

t_E : Expected run-time,

t_S : System time,

t_R : Red light waiting time,

$t_{z\min}$: Holding time,

$t_{z\max}$: Maximum holding time,

t : the average delay holding time,

t_z : Total holding time,

$test1$: Trial headway,

$testheadway_{min}$: The headway calculated by the minimum holding time,

$headway_s$: Standard headway,

$test1$: The deviation between current headway and the standard headway,

$test2$: The allowable deviation between current headway and the standard headway,

$tolerance$: Tolerance factor,

$speed_{max}$: Maximum Calculation speed limit,

$speed_{min}$: Minimum Calculation speed limit,

$speed_{mid}$: Suggested speed,

$speed_e$: Straight line speed,

$v_{\max}$: Maximum road speed limit,

$v_{\min}$: Minimum road speed limit,

$A = \{v \mid speed_{min} < v < speed_{max}\}$: Calculation speed range

$B = \{v \mid v_{min} < v < v_{max}\}$: Road speed limit range.

Time headway is a measurement of distance or time between two consecutive vehicles in a transit system, the time interval of two continuous vehicles' front passing a section. Generally using ht to represent the unit s/veh.

Using a multi-agent distributed control, vehicles don't need to get all the information of the whole line actually, each vehicle only needs to care about information of itself. Based on these information, each vehicle dynamically adjusts their speed and holding time using preceding vehicle's state to keep the headway stable. When each vehicle in a circuit can meet the above requirements, the headway of the whole line can achieve equilibrium, thus the individuals from local optimal performance show the system's overall optimization, this embodies the agent characteristic.

3.3. Agent Basic Logic

Agent of the control logic is as follows:

a. Main loop: doing information collection and logical judgment for a certain time interval, giving the driving advice according to the results of the calculation.

b. Accident judgment: in order to prevent accidents such as communication interruptions leading to the incorrect driving advice, the agent installed in the vehicle shall check the system if it is running normally firstly for each logical judgment, including whether vehicles can communicate with the preceding vehicle, and send and receive information normally. If passing the examining criterion, they continue to do subsequent calculation work of information collection, otherwise prompting system error, no longer giving advice on driving, and notifying the subsequent vehicle to transfer corresponding vehicle ahead.

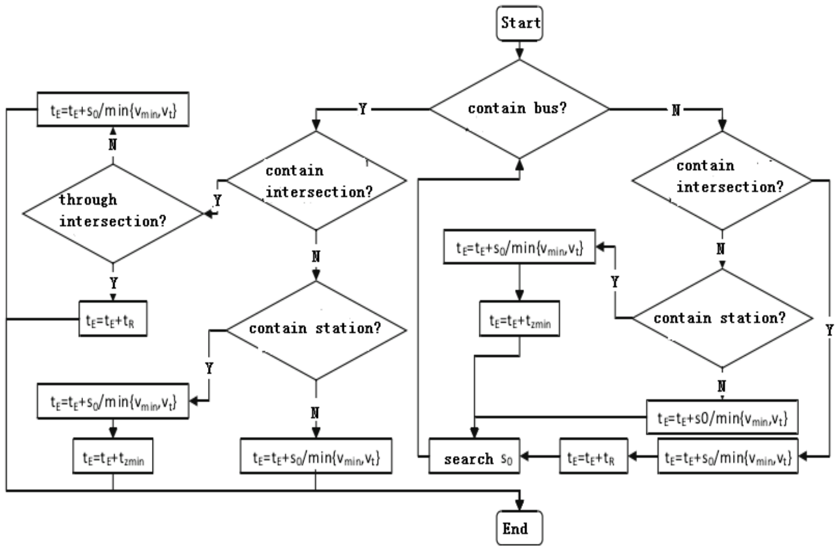

Fig. 1. The headway computation logic diagram.

c. The headway computation: As shown in Fig. 1, real-time information is used to calculate itself and the headway of preceding vehicle, calculating the difference value between computing and the standard values.

d. holding control: Judging whether difference value (Positive values for distance too far, negative value distance too close) is outside the tolerated range. If the difference is greater than the tolerated range, suggesting to adjust the headway to standard value or whether to adopt holding control, otherwise, not suggest speed adjustments or holding control and jumping out of the logic decision.

e. If vehicle adjusts speed in the next moment, it should base on four conditions of acceleration and deceleration of vehicle's performance, the current road speed limit , the maximum secure speed as the constraint of ideal speed's calculation, intersecting as the final suggested speed of auxiliary driving system. If the vehicle adopts holding control in the next moment, it should determine whether the holding time beyond the holding time, if so, even the vehicle need to extend the holding based on the headway balanced target, it will also prompt the driver away from the station.

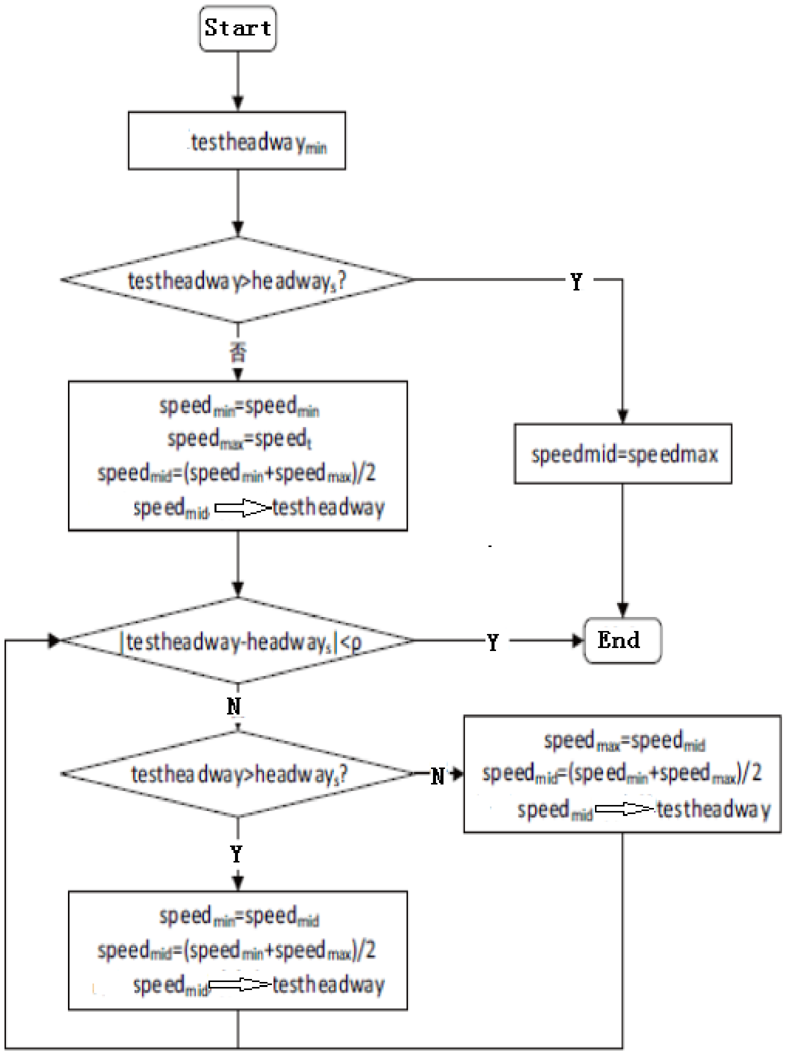

Fig. 2. Suggest the speed calculation.

The above agent in logic involved two key issues: the headway and ideal speed calculation, the following will be explained in detail:

The headway calculation:

The general definition of the headway is the time difference of two adjacent vehicles through the same section, but here the headway is different with general definition, the use of the headway concept refers to the bus fleet in two adjacent vehicles "time distance". As a result, the headway of two adjacent vehicles can be seen as expected to the latter vehicle that is required to be the current state of the preceding vehicle. Assume that two adjacent vehicles have N stations, M intersections and the length of the road, taking the current speed of the latter vehicle and the speed limit road intersection as speed, taking holding time of each station , the latter vehicle from the current position moves forward, when encountering the traffic light, it can extend the time according to the known phase expected , thus we can calculate the time when the latter car arrives at the current location of the preceding vehicle.

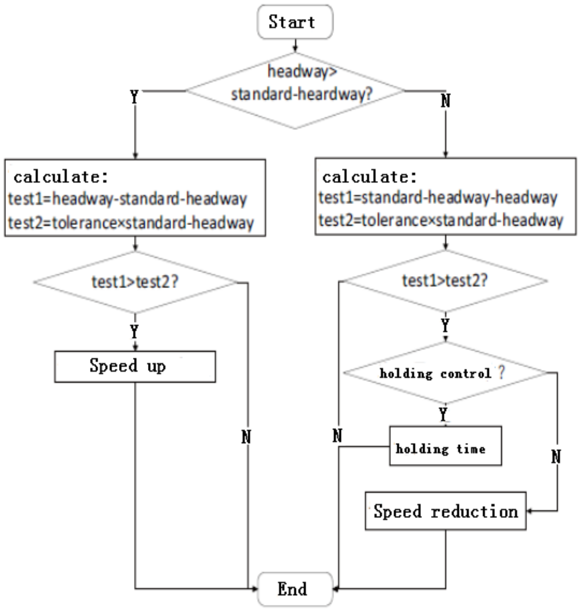

Fig. 3. Deceleration, station of judgment.

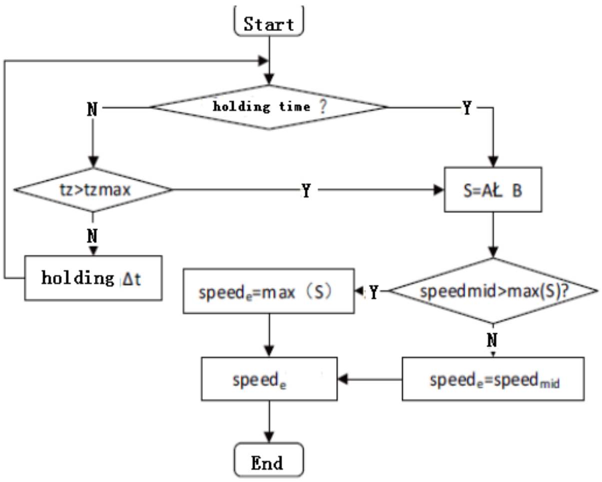

Fig. 4. Operational control logic diagram.

$$h = \frac{S_0}{\min(v_i, speed_{mid})} + \sum_{z=1}^{N} t_z + \sum_{r=z}^{M} T_r \qquad (1)$$

The ideal speed calculation

Ideal speed calculation can be simplified as seeking for the corresponding operation speed under the condition of fixed “time distance” (standard headway). So, the solution is the headway of the inverse function of ideal velocity calculation expression, we can use a computer program to back step in a similar method.

4. Model Simulation

4.1. Creating Agent

Netlogo software can create different agent according to our needs, each intelligent can do distributed independent operation, in order to the simulation demand we create three types of agents: buses, station and intersection, three types of agents in the simulation of the form are shown in Fig. 5, bus is shaped as car image, the station and the intersection is shaped as point , but all the color of the station is set to grey to distinguish with intersections and sections, color of intersection changes over the system time, red for the red light phase, green represents the green light phase.

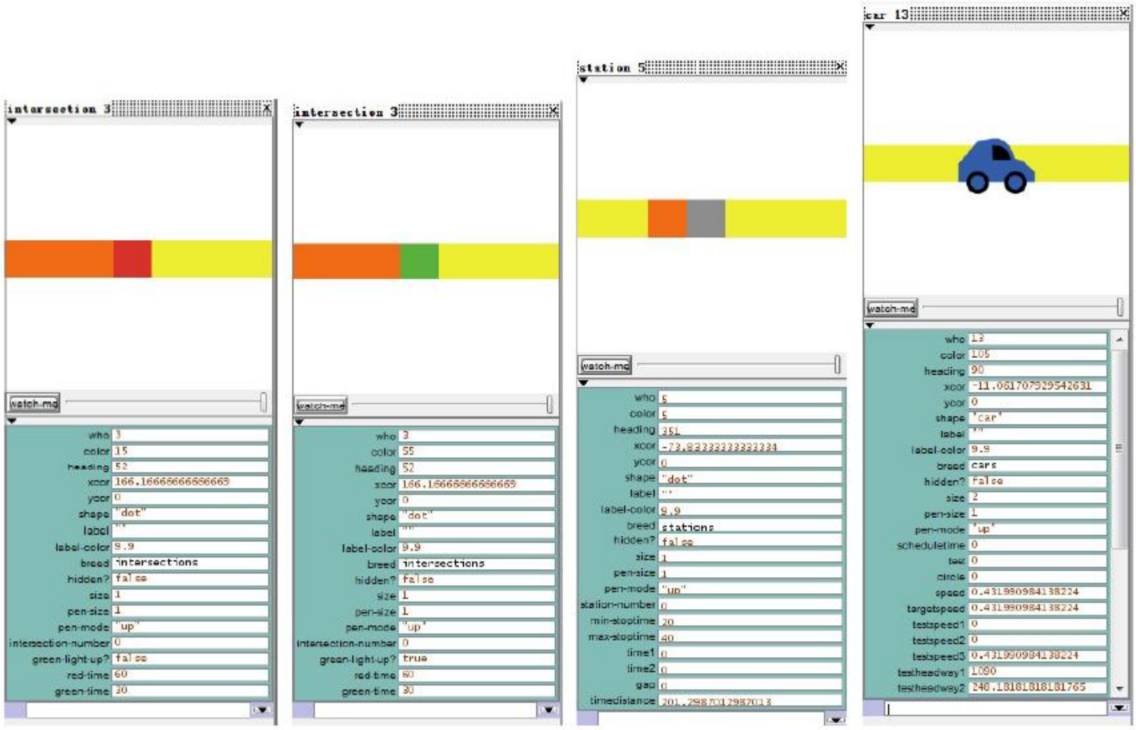

Fig. 5. Different forms of agent.

4.2. The Running Results and Evaluation

According to the way mentioned above to build simulation platform shown in figure 6, including the interface at the top of the simulation, parameter input area of the lower left and control button and the graphics area of the lower right. The lower left corner of the survey area is used to input the specific parameters to generate the corresponding simulation circuit, also includes an ON - OFF switch to control the random congestion on the road, to check strategy under the condition of the traffic congestion and external stochastic factors of the ability to adapt. The lower right button area is used to generate and control the vehicles running in a certain strategy, graphics window can record station interval in real time, intuitively reflecting whether the vehicle's arriving station time is balanced and the strategy is effective from the angle of passengers.

In this paper, through the system simulation to generate a bus lines, Fig. 7 and Fig. 8 are four different strategies of the headway distribution. The strategy 1 refers to design strategy of "back vehicle considering preceding vehicle ", strategy 2 refers to the design strategy of " vehicle considering preceding and back vehicle at the same time ". Strategy 3 is a free driving, strategy 4 is based on the schedule control strategy. It can be seen from the intuitive station interval graph that the smallest station interval volatility is based on the strategy 1 and the schedule control, the following is to evaluate four strategies respectively.

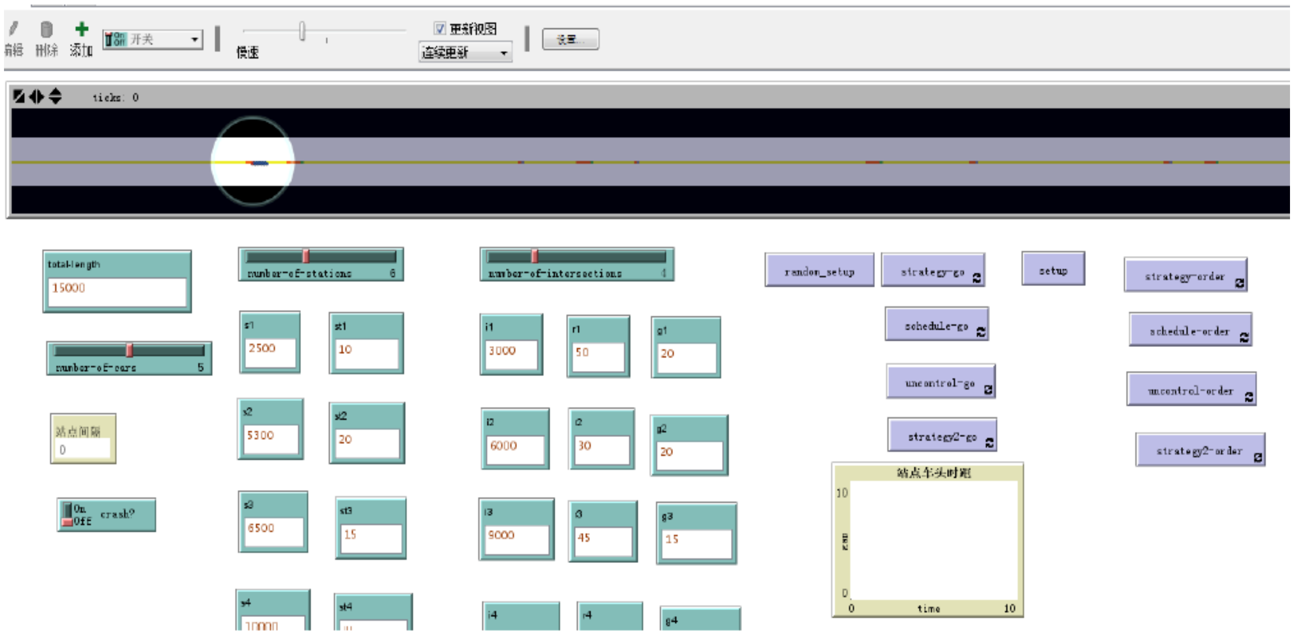

Fig. 6. The simulation platform.

Strategy 1 adjacent vehicle station intervals is in a smaller range from start to finish, the maximum and the minimum gap is less than one 6 of the average, calculation of standard deviation is the least of all strategies, which means it can guarantee the balance of the headway under the control of the strategy and is the most suitable strategy for the requirements.

Strategy 2 is designed according to the headway balanced target, but the actual simulation results is poor. Results show that the headway of the standard deviation is large, arriving interval volatility is obvious, the second is that in the practical application it can visually see the vehicle running speed is not stable, and from the perspective of the average of the strategy operation, its value is significantly more than several other control strategy, the reason is the recommended speed cannot calculate the specific values like strategy 1, only according to the proportion of the headway differences.

The average interval of free driving is the smallest, this is mainly because the fleet allows all of the vehicles' speed running at high speed, the control strategies of its circulation speed is greater than the other, but at the same time, the station interval of free driving is most volatile, illustrating the driving strategy is unfavorable for the fleet to balance the headway distribution, as for the urban high workshop isolation circuit, such serious station interval imbalance is hard to accept. According to the free driving strategy , it's easy to cause bus bunching , which is not conducive to bus lines' level of service .

The schedule control strategy is a suboptimal strategy in the four strategies, it can be seen clearly from the headway distribution, under the control of this strategy, the interval is very stable at the beginning, but as the system continues to run, once a vehicle meet with a larger disturbance (such as suffered two consecutive three red light), the entire fleet of the headway towards to the more and more differentiated direction, the arriving station interval differentiation will also be more and more apparent, it can be seen from the figure 10 that this strategy is vulnerable to the interference of the external environment and is difficult to guarantee the headway of equilibrium.

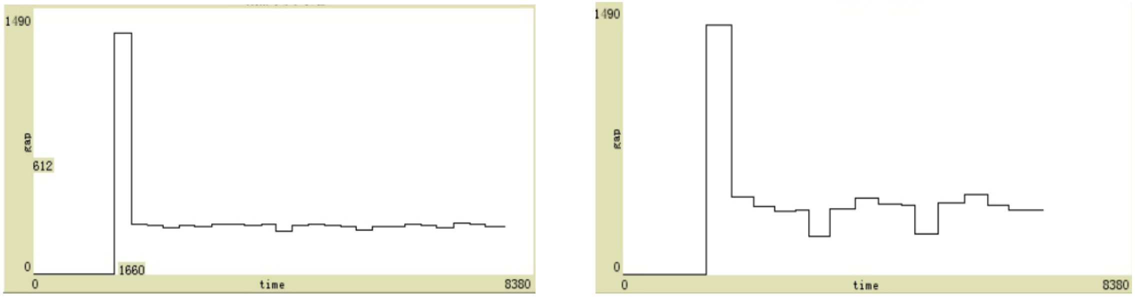

Fig. 7. The headway distribution of strategy 1 (left) and Strategy 2 (right).

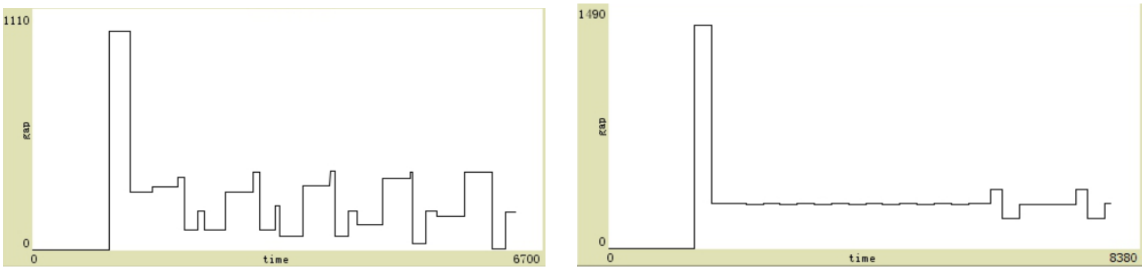

Fig. 8. The headway distribution of strategy 3 (left) and strategy 4 (right).

5. Conclusion and Discussion

According to the simulation results, it can be seen that this article based on multi-agent thought puts forward the preceding vehicle as the standard and calculates the headway of vehicles, therefore the corresponding speed suggestion of the intelligent algorithm is very effective and is a good way to deal with the interference produced by accident. And by setting the road speed limit and simulating the possible accidental road congestion, the results show the control strategy has a good ability to resist interference. If it is possible for further research, this article hopes to verify the effectiveness of the client terminal in the actual bus operation and develop the corresponding software.

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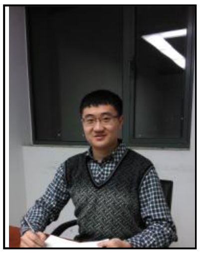

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