Path Selection of Urban Public Transportation Based on Artificial Intelligence Ant Colony Algorithm

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Abstract — Objective: to analyze and study the urban public transportation system and ant colony optimization algorithm, and propose the optimal route choice model based on GBAS. Method: theoretical analysis and algorithm analysis. Process: On the basis of detailed analysis of urban public transport system, a public transport network topology model is established, and the combined method of bus station and route is given in order to facilitate the processing of transfer in the optimal path selection algorithm. At the end of this paper, the classical shortest path algorithm is presented, and the shortcomings of the optimal path are analyzed, and the optimal path selection algorithm based on GBAS is proposed. Result & Analysis: The system which is based on the classic shortest path theory needs to be improved, and should take the actual situation of passenger travel into account. Result: The model can provide the information service for the passengers' travel.

Keywords - GBAS; Urban Public Transport

I. INTRODUCTION

A. Urban Public Transport System

The public transport system is the core of the urban comprehensive transportation system. It provides various kinds of passenger services for the urban residents in order to achieve high efficiency and safety. The biggest characteristic of public transport is that it is to the public. For example, any one can choose to travel by bus as long as he complies with the rules of public transport and is willing to pay a certain amount of travel expenses. The main body of the public transport system covers the normal bus transit (NBT), bus rapid transit (BRT), and rail transit system (RTs) for large capacity transportation. It also includes taxis and ferries and other auxiliary means of transport. The city bus system is shown in Fig.1.

1) Normal Bus Transit

Urban conventional public transport system is a traffic system which is composed of public electric cars and cars running on the city road. Conventional public transportation is the most important form of public transportation in the city. Even in the track transportation system, the rapid transit system, as the dominant city bus system, also plays an important role. It has the connection of these two types of large public transport systems, and aims to improve the bus station coverage rate for residents, provide convenience and facilitate other important functions (Tirachini, 2014).

The main features of the conventional public transportation is discussed below. First, it is affordable since ticket is cheap. It can meet the needs of low-income urban citizens for basic travel need and also provide certain concessions for the elderly, students and other special groups; (2) Second, it is at the lower speed because generally there is no bus lane setup for the conventional public transport. The social driving vehicle is big with low running speed. In recent years, the running speed of bus has dropped to less than 10km/h in the large cities of China; Third, in a moderate volume, a conventional bus lines of one-way has the passenger capacity of 8000-12000 people; 4 line network has high density, with wide scope of services, which can eliminate some bus. Conventional bus complies with less restrictive road conditions. It is layed out in city branch in order to improve bus station coverage and provide travel services to the maximum of the residents. However the hardware facilities and service performance are not sufficient and there are a lot of issues for the conventional public transportation in the configuration of the vehicle in terms of comfort and safety and passenger service attitudes (Chatterjee, 2015).

2) Rapid Transit Bus

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Fast bus system is a new type of public transport system between rail transit and conventional bus. It is another large transportation system, which is usually called "the subway system on the ground". It uses modern public transport technology with intelligent transportation and operation management, set up the construction of the road and the new bus station, in order to provide rail transit service and meet the standard of rail service. It is a unique urban passenger transport system. It has advantages of high quality, high efficiency, low energy consumption, low pollution, low cost of public transport form and is fully embodied with the people-oriented concept and strives to build a harmonious society. The rapid transit system uses advanced public transport vehicles and high quality service facilities and takes special road space and therefore it can provide fast, punctual, comfortable and safe service. Fast bus system is mainly composed of six parts: BRT vehicle, BRT platform and hub, BRT operation of the road space, BRT line, BRT toll system and BRT management system, etc. (Nunes, 2014).

3) Rail transit system

Urban rail transit system mainly includes the subway, light rail and suburban railway. Compared with conventional public transport systems, rail transit system has a lot of advantages, such as large transport capacity, fast speed, low energy consumption, long service life, low cost, no occupancy or less occupation of land. However, the initial investment in rail transportation system is huge, the construction is complex, the construction period is long with low flexibility. It is very difficult to be built, and the cost is very high. Experience from foreign large cities shows that only when the passenger traffic hits a certain number of large volume in the subway or other effective means of transport, the model is economic otherwise it is difficult to solve the problem of passenger transport economically. The data of several large cities in the world, which is listed in China Transportation and Transportation Engineering Handbook, shows that the passenger flow of the peak hour is more than 9000 passengers (Jain, 2014).

In China’s public transport system, the conventional bus is still in a dominant position. In the country, as long as there is a public transportation system, there would be a regular bus bound to the city. Even in Guangzhou, Shanghai and other cities, the rail transit system plays a major role in the daily commute to the city of urban residents.

B. City Bus Line Network

Bus line network is composed of public transport lines; the bus line is a fixed line of vehicles running, is connected by a bus station in series. Whether the layout of the urban public transportation line network is reasonable has a great influence on the operation efficiency of the whole city. The reasonable layout of the public transportation line can make the number of residents of the public transport trips to the least, for the bus scheduling and vehicle configuration and the optimization of the allocation of personnel, so as to improve the operating efficiency of the system, increase the attractiveness of public transport. Therefore, the research on the optimization model of public transportation line network is a hot spot in the domestic and foreign research (Bose, 2015; d’Arcier, 2014; Bulíček, 2015).

The layout of a city bus line network is closely related to the layout of the road network in the city. From the perspective of the strategic structure of urban public transportation line network, it can be divided into three categories as follows:

1) A central terminal facility is provided with a radial network

This shape of the line network commonly used in small cities, the highest density of travel in the city is generally concentrated distribution in the city center to the outskirts of the radial line, in other words, the largest passenger traffic
lines located in the city center and suburban district or residential area.

Radial line along the main direction of the passenger flow, the city center has an end point, and the rest of the terminal are located in the suburbs. Along the direction of the city, the traffic is gradually reduced. In order to make full use of the system capacity, it can set up the short line operation, that is, the vehicle runs to some intermediate station, and then fold back to the starting point; it can also be divided into several branches of a radial line, increasing the network coverage of the suburbs. The radial line is mainly for commuter travel services, there is a clear peak passenger flow.

Radioactive network has the advantages that the passengers only need to make no more than one time in the passenger corridor, and the non linear coefficient of the line is generally low, which can greatly save the passengers' travel time. However, due to the end of the station is mostly set in the high population density, land tension, space is limited, such as the central city, not only the streets crowded, the construction cost is also high, it is difficult to achieve the peak period of storage.

2) **Trunk network of feeder and feeder line**

Radiation type network in the center of the city traffic, suburban passenger flow is very small, so with the line gradually deepening suburb, trunk need is divided into a plurality of smaller carrying capacity of the junction. According to the design and operation of the different, the line can be divided into two categories: the direct extension of the trunk line into a branch line; independent of the trunk line to connect line. Feeder lines are the same as the trunk and the trunk, and the feeder lines are not the same as the main route. Even if the traffic is the same, the vehicle type (such as small buses, articulated vehicles) or vehicle power (e.g., diesel) is also different.

This form of bus line network can enhance the rate of bus passenger and trunk lines and lighter line spacing can be adjusted to any selected capacity levels, it is often used in a big city subway, light rail and bus rapid transit system.

3) **A radial network with a ring or tangent line**

Tangent line is the tangent direction of the city center, in the road network for the grid type of the city is more common, this line is usually for shopping, and other activities of the service, the line may be separated by a number of blocks. Compared with the radial line, the demand of the tangent line is small, and there is no obvious peak. Link radial line direct connection center city (inner ring) around a number of high population density area, effectively expanding the passenger flow distribution, through the type of line network, although residents travel need to transfer two times, but can avoid the crowded city center.

On the whole, this kind of line direct travel rate is high, travel time is short. As the tangent line to the line, the center of the travel volume can be reduced to a minimum, can adapt to travel needs of the city, and has a good travel standards and high production efficiency.

C. **City bus station**

Bus stop is the bus network node, is the bus system for the city residents to provide transport services interface, bus station is an important part of the city bus system. The performance of the bus station can directly affect the use efficiency of the public transportation system, its location, form and operation management will affect the operation of the traffic flow in the road and intersection, thus affecting the traffic capacity of the whole road network. According to the function of the bus station, the location of the station, the platform type, the bus stop has a different classification method.

1) **According to the functional classification of the site**

Bus station by function can be divided into two basic types of site, led by the end of the station and the station.

First terminal station: the starting point of the bus line, the terminal station, for the operation of the vehicle to the hair and passengers on the bus, get off the service. At the same time, but also the dispatching personnel organization of vehicle operation, Sishourenyuan rest and team learning places. Due to meet the needs of vehicle U-turn and train dispatching function. At the end of the first station generally need to set up outside the urban road land.

Stops: midway station set up in the bus line along the road after road, along the street layout is off supply lines operating vehicle docked halfway and leaving and passenger service facilities. In the middle of the station, the passenger flow distribution capacity is relatively small, generally set in the city road.

2) **Set the position classification**

Depending on the location of the bus stop station, the following three categories can be divided into the following categories:

(a) upstream bus stop at the intersection
Also known as the Near-side bus stops (NS), referring to the intersection of the upstream area of the intersection set up the bus stop. For this kind of dock, the influence and control of the traffic signal lamp and the queue length of the road motor vehicle.

(b) downstream bus stops at the intersection
Also known as the Far-side bus stops(FS), referring to the intersection of the downstream area of the intersection of the public transport station. For such a bus stop, the bus station may affect the traffic capacity of the whole intersection, increase the delay time and reduce the traffic capacity of the intersection.

(c) road bus stops
Also known as Mid-block stops(MS) , referring to the bus stop at the intersection of the two intersection, the bus station is not affected by the intersection.

3) **According to the platform form**

According to the different form of bus stops, it can be divided into the following two categories:

(a) roadside stop bus stop
Roadside stop bus stop is the traditional public transport stops in the form, which will be directly set up in the parking area in the motor vehicle lane. For such a form of bus station, bus stop when a motorized vehicle, forming a traffic
bottleneck, which will have a great impact on the normal driving of social vehicles and public transport vehicles, when the saturation of road vehicles will even make a deal with obstruction.

(b) port bus stop

Harbor type bus stop is a proper way to widen the road, and set the parking position of the bus stop in the normal driving motor vehicle to reduce the impact of the traffic bottleneck which is formed when the bus stops.

II. ESTABLISHMENT OF THE MODEL OF URBAN PUBLIC TRANSPORT SYSTEM

A. Bus Station and Line Model

Urban public transport network is connected by bus station, the bus line is not completely connected, only with the transfer connection arc section can be composed of a complete public transport network. Many roads in the city road network are connected by the intersection, and the vehicle can enter the other road from a section of the intersection. In the road network connectivity of the two nodes, in the public transport network is not necessarily connected, for example, although there is a road connecting but no bus line to reach a certain point. In the conventional public transport network, multi bus lines can intersect at the same point in space, but the point is not necessarily a bus stop site, or not at the same time, and therefore different bus lines in this is not connected, passengers will not be able to transfer at this point (Rodríguez-Núñez, 2014).

Because the site depends on the route, and route and route between the site is not connected, so the bus network is through the bus station in the following three forms to achieve connectivity: 1. The same bus lines in the same bus line in the same site through the transfer to achieve connectivity. In the establishment of the optimal route choice model, it is necessary to combine in the same location or distance from the bus station, which is used in the public transport network. In the famous traffic planning software developed by TransCAD company, we need to establish the public transportation network model, which is the important step is the combination of the adjacent bus station and the provision of the site has no travel time delay, so that the public transport network model is simplified, and the software algorithm is reduced.

In order to simplify the bus network model, the connectivity of the public transport network and the time complexity and space complexity of the algorithm is reduced, and the actual traffic network is merged with the reference TransCAD software processing method. Can bus site abstraction model reduction for the following two forms: 1. The two direction of the same bus lines and site of the same name abstraction, as shown in Fig.6; (2) for different bus lines but in transfer walk distance within the site of abstraction, as shown in Fig.7. D was said to be transfer the walking distance, in the general case D is equal to or less than 300m (Fei, 2014).

Under normal circumstances, a road bus line has two directions, and thus on the bus network diagram node, each direction on each side of the side and into the side, a total of four sides. While the same road has a number of bus lines, so there are more than two of the number of arcs between the adjacent site, the number of arc segments by the number of public transport lines n decision. Under normal circumstances, the number of arcs is num=2n. The arc between the two sites is the basis of public transportation network connectivity. The actual bus line is a direction, the starting point and the destination of the bus line to determine the path and direction. Different routes have different routes and directions, even though the same bus, the road and parking on its upper and lower traffic may not be completely overlapping, so the bus network map should be in a direction, which can not be reflected by the side of the side. Therefore, in the public transport network, it should be introduced to the line set, and the space location of the same node and arc section of the nature and weight in different lines is different, in addition, the same road on the same road, the number of stops and the number of stations is different, these differences can only be reflected in the line (Zaidi, 2014).

B. Bus Network Model

Public transportation network is a subset of urban traffic network, the same can constitute a connected network diagram, it is from the bus station and the site between the arc section. The nodes in the network diagram represent the
post merger bus station, which is the starting and final station, the transfer station and the general site. The arc section of the node in the network diagram is a bus line, which can be either one-way or two-way, and one way is corresponding to a single line in urban traffic network. Typical city bus lines are shown in Fig.8.

Figure 8. Typical city bus line network diagram.

Bus line network is a directed graph, this article will be expressed as $G \{N(N_D,N_I,N_C),A,W\}$, and $N(N_D,N_I,N_C)$ was expressed as the collection of sites, where $N_D$ is the collection of the starting and terminal station, NT is a collection of transfer site, $N_C$ is a collection of General intermediate stations. $A=\{\{N_i,N_j\},\{N_i,N_j\},\{N_i,N_j\},\{N_i,N_j\},\{N_i,N_j\},\{N_i,N_j\},\ldots\}$ is said to be the connecting link between the bus station, where $\{N_i,N_j\}$ indicates the direction of the bus line to the site $N_i \rightarrow N_j$; $\{N_j,N_i\}$ indicates the direction of the bus line to the site $N_j \rightarrow N_i$. $W=\{D_{ij}|i,j \in N\}$ indicates that the non negative weights of the connecting link between adjacent two bus stations, the average travel time between adjacent two sites or the distance between adjacent two sites, in this paper refers to the distance between adjacent sites. $R=\{R_i\}$ represents a collection of all bus routes for the entire bus line; $R_i=\{N_i\}$ represents a collection of all bus stops on the Ri bus; $N_i\{R_i\}$ represents a collection of all bus lines passing through the transfer point NT (Circiu, 2014; Rungraengwajjake, 2015).

III. FEASIBILITY ANALYSIS OF GBAS FOR SOLVING THE PROBLEM OF CHOOSING THE ROUTE CHOICE OF BUS TRAVEL

A. Bus Travel Route Choice Problem and Traveling Salesman Problem

The first ant colony algorithm (AS) proposed by Dorigo Macro is used to solve the traveling salesman problem. Since then, many scholars have tried to improve the basic ant colony algorithm, and have achieved success. The essence of ant system (EAS), ant colony system (MMAS), ant colony system (ACS), ant colony system (PACS) and ant colony system (RAS) are proposed. All these algorithms are tested on the traveling salesman problem, and the efficiency of the algorithm is improved. Therefore, the traveling salesman problem has the important function to promote the development of the ant colony algorithm. Traveling salesman problem is also the shortest path problem, but it has a certain difference in the shortest path and the optimal path of the paper, the following will be the travel business problem and the travel route choice problem.

1) The traveling salesman problem (TSP)

Intuitively speaking, traveling salesman problem (TSP) is the problem that the businessman encounters in the course of business, the businessman from the city of his own, hoping to find a way to pass a given customer in the city, but also in front of the home to visit every city once the shortest path. The TSP problem can be represented by a weighted complete graph $G=(N,A)$, where $N$ is a collection of $n=|N|$ points (cities), and $A$ is a collection of edges that are fully connected to these points. Each edge $i,j$ and $A$ with a weight of $D_{ij}$, which represents between the city $i$ and city $j$ distance. The TSP problem is to find the shortest Hamilton loop in the graph, which can be found in each of the points in the $G$, and only one of the closed loops. In addition, the traveling salesman problem also for the symmetric traveling salesman problem (TSP) and non symmetric TSP problem (ATSP); in the symmetric traveling salesman problem (TSP), the distance between the city and walking in the direction of the boundary between the city of independent, that is, for each point to have $d_{ij}=d_{ji}$; and for the asymmetric traveling salesman problem (TSP), at least there two points I and j, among them $d_{ij} \neq d_{ji}$. The solution to a traveling salesman problem can be represented by a number of cities; this arrangement is cyclic, and the absolute position of the city in this arrangement is not important, but the relative order of the city (in other words, the same solution may have different rows, but in fact, the relative position of the city is the same).

2) Bus travel route choice problem

Urban public transport network can be represented by a directed graph $G=(N,A)$, that is, there is not necessarily a two-way communication between nodes on the bus network. Bus travel route choice problem is to find a minimum number of transfer times on the directed graph $G$, travel distance is the shortest (static route choice) or travel time is the shortest (dynamic path selection) of the optimal path. Bus
travel route choice problem and TSP mainly exist in the following several points:

(a) TSP is a complete graph, and the choice of bus travel path is a directed graph, which leads to the existence of different nature of the problem.

(b) TSP requires that all nodes in the complete graph, the ACO is used to solve the TSP problem, and the artificial ants must traverse all the nodes, and the bus travel path problem is not required to traverse all nodes of the bus network.

(c) There is no transfer problem in TSP, but the length of the path is considered, and the number of the transfer times is the primary objective of evaluating the travel path.

(d) Obtained by 4 tsp solution is used to indicate the serial number of the city a permutation, and the arrangement is a ring structure, and bus travel path for the solution is just a sequence of bus stops, and could not for the cyclic structure.

From the above analysis, it can be known from the above analysis that the route choice problem is more complex problem than the TSP, and the ant system (GBAS) based on graph has some characteristics which are in line with the route choice of public transportation network. This is the original intention of using GBAS algorithm to solve the problem.

B. Solving Feasibility Analysis

From the above GBAS structure analysis, the bus network diagram is not in line with the last node in the path of the directed graph G no successor node, the request. In the process of selecting the best route selection algorithm based on GBAS, the algorithm can be processed in the process, so that it can form a feasible solution.

The feasible solution is a key step to solve the problem. The feasible solution can be used to analyze the advantages and disadvantages of the correlation function. Based on this consideration, the author will use the GBAS algorithm to solve the problem of bus travel route choice. In the fifth chapter, the author will use VisualC++ to implement GBAS bus travel route choice algorithm, and prove its feasibility.

IV. BUS TRAVEL ROUTE SELECTION ALGORITHM BASED ON GBAS

On the basis of the urban public transportation network, this paper uses GBAS to solve the optimal path between the and the target site Ns to the target site Nt:

Step0: Urban public transportation network is expressed as \( G\{N(N_o,N_f,N_i),A,W\} \), and the initial value of \( L(s) \) for each arc segment of the bus network is \( \tau_0 = \frac{1}{n} \) (n is the total number of segments between two stations in the entire transit network); \( \eta_j \) is as a section of Road (i, j) of the heuristic information, \( \eta_j = \frac{1}{d_i} \). Selection of ant colony size M clustering scale is m (M is an integer of m plus 1 times the number of iterations), nc=0. Step1: (outer loop) ant clustering began to work. Every one of the ants from initial bus station ns, L(s) was expressed ants walk after the bus site collection and initial L (s) is empty and s <= m.

Step2: (inner loop) clustering ant algorithm is calculated according to the following. The ants are placed in the starting site Ns, the number of transfer t=0.

(1) The ants in the bus station Ni, if Ni=Nt is complete, calculate the s ants, turn the steps; otherwise the transfer procedure.

(2) To determine whether True is \( N_t \in N_T \) (Ni is the transfer site). If the True, the steps, otherwise go to step 4.

(3) At this time, in the site Ni have different bus routes can choose, ant s to the probability of \( N_t \in N_T \) transfer to the next bus station Nj.

\[
P_j(s,L(s)) = \frac{\sum_{\text{everyline}k} \tau_0 ^{\alpha} \eta_j ^{\beta}}{\sum_{\text{everyline}k} \tau_0 ^{\alpha} \eta_j ^{\beta}} \quad \text{if } N_{ij} \neq L(s) \text{ and } N_i, N_j \in A \quad \text{other}
\]

wherein, \( \alpha \) represents the relative importance of pheromone (\( \alpha = 0 \)); \( \beta \) represents the relative importance of heuristic information (\( \beta > 0 \)).

Judge whether the passengers on the site Ni transfer.

According to the collection of \( N_T \{ R \} \) to get through the transfer station Ni all the lines, and then search the line set \( R = \{ N_i \} \) in each of the site. If the Nj in the original on the bus line, the passengers did not change at Ni point; if the Nj is not on the original bus line, the passengers in the Ni point of a transfer, t=t+1. Judge t>3, the trip through the path of the invalid travel path, the ant will naturally die, turn (5); Or L(s) = L(s) ∪ \( \{ N_j \} \), \( N_i = N_j \), then turn (1).

(4) If \( N_i \notin N_T \), then \( N_i \in N_e \). In this case, the bus vehicle along the original route, not to change. L(s) = L(s) ∪ \( \{ N_j \} \), \( N_i = N_j \), turn (1).

(5) s=s+1, if s<m, then turn step 2; Or s=m, turn step 3.

Step3: for A, the length of L (s) and the number of trips to the starting point of the trip are t. The length of L (s) is compared with that of the (T), and the shortest path is the optimal path; Otherwise, the least number of times of the transfer path is the optimal path. The number of ants in the optimal path is k, if \( f(L(k)) < f(L(s)) \), then \( op = L(k) \) (op, optimalpath). Ants in the section \( \{ N_i, N_j \} \) on the length of the path of the number of units in the path of the value of \( \Delta \tau_{ij}^k \):

\[
\Delta \tau_{ij}^k = \begin{cases} \phi(op) & \text{if } \{ N_i, N_j \} \text{ is on the op.} \\ 0 & \text{other} \end{cases}
\]
Wherein, $\phi(op)$ is non increasing and op variable non negative function, it in a certain extent dependent on ant former $nc-1$ in the outer loop through the optimal path. Using the formula 3 to enhance the information on the optimal path $op_{ij}(nc)$, the information on the other path of the volatile:

$$\tau_{ij}(nc) = \frac{(1-\rho_{nc})\tau_{ij}(nc-1)+\Delta\tau_{ij}}{(1-\rho_{nc})\tau_{ij}(nc-1)}$$

If $\{N_{Ni},N_{Nj}\}$ is on the op, \(\text{other}\)

the new $\tau_{ij}(nc)$ was got, and the volatile rate of $\rho_{nc-1}$ is expressed in the formula.

When a better solution than the current optimal solution, the pheromone update rule will update the pheromone.

$$nc = nc+1, m$$ , then turn step1. Otherwise, the end of the whole algorithm, the output bus travel route optimization.

In Step3, after a single cycle, there are $k(1 \leq k \leq m)$ ants go the optimal path Op.

$$C = \sum_{i<N_{Nj}} \sum_{j\neq N_{Nj}} \Delta\tau_{ij}$$

If $C=0$, then for all public transit arc network $<Ni,Nj>$, there is

$$\tau_{ij}(nc+1) = \tau_{ij}(nc)$$

If $C>0$, then

$$\Delta\tau_{ij} = \frac{1}{C} \sum_{c=0}^{C} \Delta\tau_{ij}$$

Ant with a certain probability from the Ni site to site Nj transfer, pheromone updating is in Step3, completed after a grouping of inner loop iterations, the online sections of the bus line information of an update. Assuming that the $\tau(nc) = \{\tau_{ij}(nc)\{N_{Ni},N_{Nj}\}} \in A\}$ and the current optimal solution $op(nc)$ are obtained by the and the nc. The pheromone and the optimal solution for the first NC cycle is $\{\tau(nc-1),op(nc-1)\}$. The step by step from the ants in the transfer point is random, and from $\{\tau(nc-1),op(nc-1)\}$ to $\{\tau(nc),op(nc)\}$ is also random, so the $\{\tau(nc),op(nc)\}$ is a Markov process.

V. CONCLUSION

In this paper, the model of public transportation is established. It illustrates various public transportation system, studies the general public transportation system, and the line network and site type of the bus system. Based on the research of ant colony algorithm, the incremental traffic assignment model is proposed. It is found the basic ant colony algorithm is a suitable solution in this case. Then, the optimal path selection algorithm based on GBAS is proposed. It believes that providing information service for passengers' regular bus travel has certain academic value and practical significance.

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