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Traffic Network Optimal Scheduling Paths Based on Time Intervals Division

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Abstract

In order to make the network model was more fitting the actual condition of city traffic, this paper presents a dynamic transportation network model based on the traffic time division, and designs improved Dijkstra algorithm to solve the city traffic paths planning problem. Dijkstra algorithm is a typical single-source shortest path algorithm is used to calculate a node to all other nodes in the shortest path. The main characteristic is the starting point as the center outward expansion layers until the extension to the end. The Dijkstra algorithm is a very representative shortest path algorithm. This paper introduces new patterns to effectively combine the model and algorithm. The simulation experiments point to ten time intervals which illustrate the improved Dijkstra algorithm can avoid driving to the blocked roads in different time intervals. The algorithm has some feasibility in path planning and computation efficiency.

Keywords*: path planning, road network model, time division, improved Dijkstra algorithm*

1. Introduction

In recent years, with the rapid growth of car ownership, traffic problems have become a very serious social problem which causes great inconvenience for people's daily life and work and also bring environmental pollution, waste of energy, and traffic jam phenomenon [1]. As an important part of the national economic and social activities, transportation has become one of the foundations of the survival and development of the modern society. With the rapid economic development in China's major cities in recent years, expanding population, car ownership in the rapid growth and traffic congestion problems caused by a series of traffic social problems . Due to the lack of infrastructure construction over the years, a lot of planning has gone wrong in the implementation process, which are reducing the efficiency of urban transport, caused some social problems. This greatly affects the social and economic development and the improvement of people's living standard. The path planning pointing to the urban traffic can solve the problems of road congestion, travel inconvenience in a certain extent [2].

In order to improve the efficiency of city traffic path planning, domestic and foreign scholars have carried on researches and proposed lots of path planning algorithms which contributed to the traffic system construction is theories and practice [3, 4]. At present, the research directions mainly focus on the aspects of road network models and planning algorithms which have achieved certain results. Among them, Zografos proposed a traffic decision-making support system which is for vehicle allocation, scheduling and routing guidance [5]; Lu Feng proposed the optimal path algorithm based on spatial hierarchical reasoning which first classified the traffic network in the forms of grades to different levels, and then the levels were used for the optimal path planning algorithm [6-8]; reference proposed a layered path planning algorithm which can increase the searching efficiency by constraining the searching areas. The road hierarchical approach is used to improve the optimal path planning; reference presented a dynamic shortest path algorithm and provided the general solutions of the optimal paths in an acyclic graph; reference and discussed the shortest path problem for arc weights changes. The previous researches mainly are for path planning problems most of which are based on shortest path algorithm. The conditions are too restrictive and the calculation methods are too complicated [9]. Although the methods can theoretically achieve the accurate calculation results, it's hard to collect the data and difficult to fulfill in the actual application [10, 11].

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Aiming at the above shortcomings, this paper proposes a dynamic optimal path planning algorithm based on traffic time division combining the current urban traffic dynamic changing features. The paper builds the road network model on basis of the dynamic changing rules of the road traffic at different time. The data collection methods in the model are simple and the paths planning algorithm has high computation efficiency. The model can well cooperate with the algorithm [12-14].

2. The Dynamic Road Network Model

In the normal road network model, there are lots of information, such as delay at crossroad, and delay due to traffic control. It's complex to collect the time information and it's hard to fulfill. Therefore, the models should be simplified according to the specific features of the urban traffic when build the models.

2.1. Urban Traffic Dynamic Changing Features

In the real traffic, there are blocked conditions in the roads. The traffic conditions will be different in the same road at different time intervals. For example, the interval of 8:00-9:00 is normally the peak time to go to work, so the blocked situation is serious. However, the interval of 5:00-7:00 will be unblocked. According to the above urban traffic changing features, it's not suitable to use the unitary time weight tpij to represents the time finish driving the directed arc <vi,vj>. Therefore, the driving time weights should be reconfigured according to the dynamic changing rules of the traffic.

Bretti proposed to build models that were close to the urban actual traffic conditions in the researches in which traffic dynamic information need to be fused in the model. Therefore, the areas with varied traffic conditions should be considered. Only the static road network model and shortest time can't simply be used to plan paths because it will make the chosen paths are not the shortest paths in the actual situations. Due to the concern, when build the dynamic road network model, not only the urban traffic varied conditions should be considered, but also the traffic conditions at different time intervals should be taken into account.

2.2. The Dynamic Road Network Model

Dynamic route guidance and traffic control is based on Urban Road Network Traffic Analysis in intelligent transportation systems.

Urban Road Network Traffic Analysis is also important to traveler information service system. City road network traffic state analysis method is the basis of important theoretical problems of intelligent transportation systems and traffic management evaluation of traffic congestion, and solve traffic congestion, this method can provide a reference for road traffic planning.

Currently, researchers at home and abroad have done some research on city and highway traffic state. On traffic state of the urban road network research, the main draw relevant conclusions get from the testing data. For example: The application of pattern recognition theory and methods, research on urban transport network and the motorway network mode, draw traffic state can be reduced to repeated, a limited number of the results of the different types of patterns; Using pattern recognition methods feature vectors extracted intersection traffic flow running condition and situation assessment model to establish traffic through the intersection data similarity; Adopting a global approach to data management analysis of space-time traffic data, to draw traffic state representation. In freeway traffic state research, mainly uses the extended Kalman filter. For example: the extended Kalman filter approach to highway traffic density prediction. Extended Kalman filter method establishes real-time highway traffic state estimator.

The city traffic webbed analysis related to the macro, Medium and micro traffic parameters. Macroscopic traffic parameters describes the evolution of the characteristics and the overall state of network traffic network; medium parameters mainly refers to road traffic parameters (flow rate, share, etc.); microscopic parameters mainly refers to the vehicle operating status and relationship to each other. Therefore, the traffic state of the urban road network analysis involves a multi-scale, multi-variable, highly random and time-varying complex systems analysis. Only temporal variation cannot draw traffic from the analysis of the traffic flow data, and the need to establish a reasonable road network model, define connected micro-, medium-and macro-city road network traffic status parameters. On this basis, the right path network traffic status and its changes analyze.

Traffic volume of generation is related with the people's production and life, and a variety of social activities. Different path at the same time, the same road at a different time or the same road at the same time in the different sections of their traffic volume may be different, and this difference and the change have certain regularity. This change is called traffic distribution characteristics that the traffic occurs with time and space different. Studying the variation of the traffic will be able to understand and master the traffic characteristics. Road traffic planning, economic analysis of road traffic facilities design, traffic management and traffic safety are of great significance.

In urban traffic, different time intervals correspond to different traffic conditions. Therefore, the driving time weights of each arc will change with the time intervals. In dynamic road network model, the 24 hours in one day can be divided to different time intervals according to the traffic conditions. If the road conditions at two time intervals are the same, the weights will be the same. Table 1 is the population statistical trip time in one day in Liuzhou city.

Table 1. Trip Time Statistical Table

	Trip time	
1	6:30-7:30	11:30-13:00
2	7:10-8:30	17:00-18:00
3	8:30-9:00	16:30-17:00

Based on the conditions in Table 1, one day can be divided to 10 time intervals (k0~k9), as shown in Table 2.

Table 2. Time Division and Related Traffic Conditions

km	Time	Traffic Conditions	km	Time	Traffic Conditions
k0	6:00-7:30	Sparse	k5	13:30-14:30	Peak
k1	7:30-9:00	Peak	k6	14:30-16:30	Sparse
k2	9:00-11:30	Sparse	k7	16:30-19:30	Peak
k3	11:30-13:00	Sparse	k8	19:30-22:00	Sparse
k4	13:00-13:30	Sparse	k9	22:00-6:00	Sparse

The blocked conditions of the traffic can be classified to 5 levels- 1 extremely unblocked; 2 unblocked; 3 slightly blocked; 4 medially blocked; 5 seriously blocked. Through the traffic conditions at each time in table 2 as well as the traffic block evaluation indexes, there are some conclusions-k1, k7 belong to peak time, the index is 5; k3, k5 are less, the index is 4; k2, k6 and k8 maybe have slightly blocked situation, the index is 3; k0, k4 are comparably unblocked, the index is 2; k9 belongs to extremely unblocked time intervals, the index is 1.

Through the previous analysis, this paper builds the dynamic road network model based on traffic time division. There are:

$$
\begin{aligned}
&G=(V,E,T,D)\\
&V=\{v_i \mid i=1,2,3,\ldots,n\}\\
&E=\{<v_i,v_j> \mid v_i\in V, v_j\in V, i\neq j\}\\
&D=\{d(v_i,v_j) \mid (v_i,v_j)\in E\}\\
&K=\{k_m \mid m=1,2,3,\ldots,s\}\\
&T=\left\{ w_{pij}^{k} \,\middle|\, \begin{array}{l} <v_p,v_i>\in E, <v_i,\\ v_j>\in E, k_m\in K \end{array} \right\}
\end{aligned} \tag{1}
$$

In the above 6 equations, G is urban road network chart, and each arc corresponds to one time weight. V is the information set of the nodes in G; E is the directed arcs set in G; D is the distance between the two contiguous nodes in E; T is the time need to finish driving all of the directed arcs in E; K is time intervals set. Figure 1 is the dynamic road network based on time division.

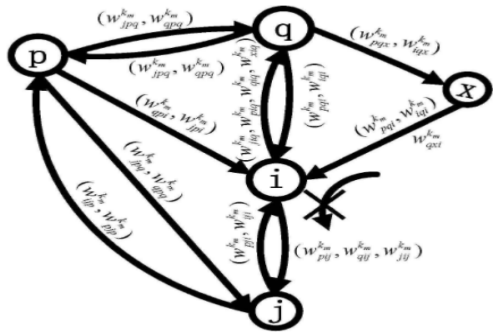

Figure 1. Dynamic Road Network Based on Time Division

In Figure 1, wkmpij represents the time finishing driving the directed arc of <vi,vj> from the precursor node vp via the start node vi in the directed arcs of <vp,vi> and <vi,vj> in the time interval of km. wkmpij includes the delay of the precursor node vp at node of vi处and the time from vi to vj. Therefore, although at the same time, the time finishing driving <vi,vj> from different directions is different. Then, at the same time, an arc will correspond to different weights. Thus, when time interval is s, there are s groups of time weights in the dynamic road network. From the previous analysis, the differences between the road network model based on time division and other models are as follows.

(1) The road conditions and features are completely considered which is in accordance with the dynamic rules.

(2) The time information of the road network can be obtained directly by GPS.

(3) Each arc can correspond to multiple weights based on precursor nodes.

(4) The actual conditions of the roads are directly or indirectly considered, such as driving time and delay at crossroad.

3. Optimal Paths Solutions in Dynamic Road Network Model

The improved Dijkstra algorithm is applied to solve the dynamic optimal path problem based on time division.

3.1. The Data Structure of the Improved Dijkstra Algorithm

In the proposed road network model, the directed arcs at each time correspond to a group of time weights. The array N stores the arcs set of E, the adjacency lists store the weight of each directed arcs in E. For mth single list, it can store the time weights when it driven the whole directed arc at time km-1. The adjacency matrix stores the pointers of the directed arcs. The pointers are used to locate the adjacency lists in the array as shown in Figure 2.

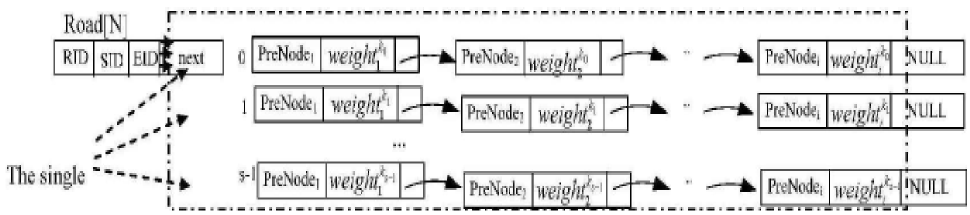

Figure 2. The Adjacency Lists Storing the Directed Arcs Weights

3.2. Computation Steps of the Improved Dijkstra Algorithm

In order to well combine the established dynamic road network model and improved Dijkstra algorithm, a new equation cost(i,j,pre,km) is introduced to represent the time weights driving from vp to <vi,vj> at time km. Then,

$$\begin{array}{l} Road\left[Windex[i][j]\right].next[k_m].w_t^{k_m}, \\ \text{if } preNode = pre \text{ and } Windex[i][j]! = 1 \\ \min\left\{Road\left[Windex[i][j]\right].next[k_m].w_t^{k_m}\right\}, \\ \text{if } pre = \text{-}1 \text{ and } Windex[i][j]! = 1 \\ \infty, \text{ if } Windex[i][j] = \text{-}1 \end{array}$$

The Equation (8) is used to initialize the algorithm. The function first computes the minimum time weight collected by the different precursor nodes in directed arc <vi,vj> at time km. The meanings of the character variables in the algorithm are as follows. S—set variable which is the set of the nodes in optimal path; s(vi)— Boolean variable which identifies whether found the optimal path to the node of vi; d(vi)—the time to finish the optimal path; p(vi)—pointer, the precursor nodes chosen by node vi; T—the time arrived at the node. The details of the algorithm are as follows.

(1) Initialization. Assume the cars leave the start point v0 at time t0, the time interval of time t0 can be obtained as km, other nodes vi can be computed by equation (8).

(2) The nodes meeting s(vi)=false are searched. False represents the optimal path to node vi doesn't find. The nodes with minimum d(vi) are counted to set of S. By computing the time of T=T+d(vi) the cars arriving at vi, the time intervals km belonged to time T can be obtained.

(3) Revision. I d(vk)>d(vj)+ cost(i,j,p(vj),km), assume d(vk)= d(vj)+ cost(i,j,p(vj)), p(vk)= vj until the paths with shortest time are found.

(4) Steps (2) and (3) are repeated until s(vt)=true. True represents optimal path of node vi is found. vt为is the end point.

(5) Recall. Based on precursor pointer p, the optimal path P0t from start v0 to end vt can be obtained, that's:

$$P_{0t} = \left\{v_0, v_1, \ldots, v_t \middle| v_i = p(v_j) \text{ and } p(v_j)! = -1\right\} \quad (2)$$

4. Experiment and Analysis

Aiming at the dynamic optimal paths planning problem based on traffic time intervals division, this paper builds a simulation experiment platform in which the platform uses the processor of Intel®CoreTM2 Duo E7500@2.93GHz, and memory of 4.00GB. The development environment uses Visual C++ and MAPX widgets. The time weights of the directed arcs in the road network model are computed as following rules.

(1) The dynamic road network situation based on traffic time division is simulated. Assuming the time weights of each road at different time are road length/speed limit and the delay at crossroad is 0.

(2) The dynamic road networks when the roads are blocked are simulated. The traffic blocks only simulate the blocks at crossroads and Rotary intersection.

Ten times of simulation experiments are carried on based on the previous rules and the traffic conditions at ten time intervals. Figure 3 is at time k0 (6:00-7:30), the traffic condition belongs to roads planning problem at idle time, Figure 4 is at time k7 (16:30-19:30), the traffic condition belongs to the roads planning problem at peak time.

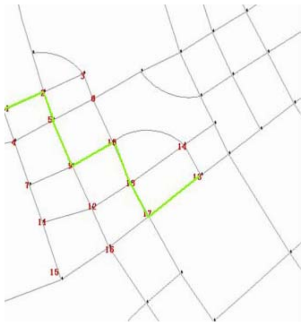

Figure 3. Optimal Paths Planning at Time k0

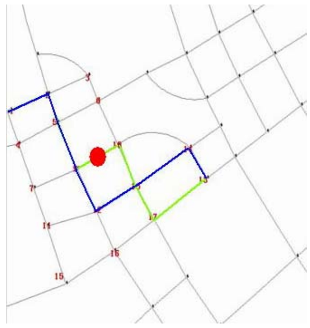

Figure 4. Optimal Paths Planning at Time k7

From Figure 3 and 4, the improved Dijkastra algorithm can avoid driving to blocked roads at different time to find other paths. The simulation experimental results at ten time intervals are as shown in Table 3.

Table 3. Simulation Experiment Results at Different Time

Time	Overall lengths of the paths (m)	Driving time (s)	Path planning time (ms)
k0	1285.68	97.28	388
k1	1897.36	2246.83	259
k2	1285.68	132.09	311
k3	1285.68	266.98	311
k4	1285.68	96.33	297
k5	1897.36	1917.58	362
k6	1285.68	157.41	339
k7	1897.36	2107.53	283
k8	1285.68	161.76	341
k9	1285.68	74.20	335

Referring the time intervals and traffic situations in Table 2 and comparing the simulation results in Table 3, the traffic situation at time k1, k5 and k7 is at peak which is more crowd than other time intervals and the driving time is longer. By combining the simulation results in Figure 4, although traffic is congested at time k7, the improved Dijkstra algorithm still can re-plan the paths and the time for searching paths is merely 283ms. Generally speaking, the improved Dijkstra algorithm can effectively plan the optimal paths in the dynamic road network model based on time intervals division.

5. Conclusion

This paper carries research on dynamic optimal paths planning problem based on traffic time division, builds simulated dynamic road network model, and presents the computation steps for improved Dijkstra algorithm which fulfills the effective combination of the model and algorithm. The road network model based on time division can truly reflect the city traffic features which has some practical value. The results of the simulation experiments prove the proposed model and computation method have some feasibility in paths planning and computation efficiency.

References

[1] Shuqiao Zhou, Peter Dely, Ruixi Yuan, Andreas Kassler. Mitigating Control Channel Saturation in the Dynamic Channel Assignment Protocol. *JCIT.* 2011; 6(6): 271-281.
[2] Guang Li, Yadong Wang. A New Method for Privacy-Preserving Data Mining Based on Weighted Singular Value Decomposition. *JCIT*. 2011; 6(3): 28-34.
[3] JIA An- chao, ZHOU Gang. Study on Selection of Suppliers Based on Rough Set and BP Neural Network. *Logistics Technology.* 2012; 31(12): 229-232.

[4] Cheng-Hong Yang, Sheng-Wei Tsai, Li-Yeh Chuang, Cheng-Huei Yang. A Modified Particle Swarm Optimization for Global Optimization. *IJACT*. 2011; 3(7): 169-189.
[5] Ying CHEN, Runtong ZHANG, Haoyue LI, Ruixia LI, Yuhong GAO. CALIS-based Cloud Library Services Platform Model. *AISS*. 2011; 3(6): 204-212.
[6] GUO Qiu-xia, DENG Xiang-ming, OU Yang-jiang. Evaluation of Value Chain Risks Based on BP Artificial Neural Network. *Logistics Technology.* 2011; 30(7): 120-122.
[7] Jirasak Gornmanee, Kittima Mekhabunchakij. Translation ITIL Service Operation to Ontological Artifacts. *JCIT*. 2011; 6(9): 271-294.
[8] Joseph K Siror, Liang Guangun, Pang Kaifang, Sheng Huanye, Wang Dong. Impact of RFID Technology on Tracking of Export Goods in Kenya. *JCIT*. 2010; 5(9): 190-199.
[9] Huang Rui. Diffusion of Mobile Phones in China: Application of Bass Diffusion Model. *JCIT*. 2012; 7(1): 54-61.
[10] QIU Shi-hui. Analog Circuit Fault Diagnosis Based on Artificial Neural Network. *Science Technology and Engineering.* 2012; 12(30): 8042-8046.
[11] Jiejun Huang, Yanyan Wu, Yingxia Wu, Yunjun Zhan, Hao Wu. Analysis of Spatio-temporal Changes of Land Use in Wuhan City Using Remote Sensing and GIS. *IJACT*. 2012; 4(1): 215-222.
[12] Qiu Chen, Koji Kotani, Feifei Lee, Tadahiro Ohmi. Face Recognition Using VQ Histogram in Compressed DCT Domain*. JCIT.* 2012; 7(1): 395-404.
[13] Zhang Lihua. A New Quantum Clone Genetic Algorithm Based Multi-user Detection for CDMA System. *IJACT*. 2011; 3(11): 17-25.
[14] Vahid Behravesh, Seyyed Mohammad Reza Farshchi. A Novel Randomized Search Technique for Multiple Mobile Robot Paths Planning In Repetitive Dynamic Environment. *IAES International Journal of Robotics and Automation*. 2012; 1(4): 214-222.