The Research on Traffic Assignment Method Based on the Urban Road Network Topology

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Abstract. As our country urbanization and economic development accelerating, traffic problems become increasingly serious. In urban road network, the intersection delay has a major influence on road impedance even the choice of the path. In order to reflect the actual situation of traffic flow distribution more accurately, the transportation network assignment model was established based on the intersection flow of delays and traffic control. By comparing delay models of signal control and analyzing the intersection impedance, the intersection optimization model was built based on delay, queuing and traffic capacity. Then, we analyzed the structure of the road network topology and traffic assignment models, researched the advantages and disadvantages of the allocation algorithm in detail. Finally, the balanced allocation algorithm for FW algorithm convergence slowly was improved. The feasibility of the algorithm was verified by examples.

1. The Research Background
At present, the traffic characteristics of urban roads mainly show the following two points: first, traffic congestion first occurs in individual sections and intersections, and is gradually spreading to the whole road network; Secondly, the traffic load in the road network is not balanced. The traffic volume of some regions has reached or even exceeded the road capacity, while the traffic volume of some regions is far from the road capacity. In order to solve this traffic situation, in addition to new roads, we should strengthen management and organize the traffic flow of urban roads reasonably. Based on the continuous improvement of traffic facilities, increasing the availability of road supply, reasonably increasing traffic demand, and carrying out effective traffic planning and management is the key to solving the more and more serious traffic problems in Our country, is also the fundamental method[1].

Traffic distribution is an important step in traffic planning and management. It can simulate traffic distribution according to the traffic planning scheme implemented by the road, and obtain various operating parameters of the road network in advance, so that the planning scheme can be evaluated effectively and reasonable suggestions can be put forward to make the planning scheme reach the optimization.

Yagar proposed the first computer-simulated allocation model, which satisfies Wardrop's user optimization criteria, and adds real-time changing traffic demand and influencing factors of queuing theory[2]. At the same time, Yagar also proposed an algorithm for this model, which is instructive, and Vanaerde and Yagar have made great changes to this algorithm. Brastow also proposed a dynamic traffic allocation model based on user optimization. This model uses the relationship between flow and density to convert the demand function that is segmented as a constant over time into a function that is segmented as a constant over distance[3]. In addition, Mahmasani, Peeta, and Jayakrishnan also proposed a computer model based on dynamic traffic allocation.
2. Traffic Distribution Method

2.1. Wardrop Balance Model
The balanced distribution model has matured in theory and solving algorithm, coupled with the acceleration of computer development, balanced distribution has been widely used in actual traffic planning.

The UE model is completely equivalent to the Wardrop principle. The state it describes is that travelers know the operating conditions of the road network and choose the shortest path for themselves. The cost of the unused path is greater than or equal to the cost of the used path. It is impossible to unilaterally change the path to reduce costs. Mathematical formula of UE model:

\[ \min : Z(x) = \sum_{a} \int_{0}^{x_a} t_a(w) dw \]

\[ \sum_{k} f_{rs}^{k} = q_{rs} \]

\[ f_{rs}^{k} \geq 0 \]

\[ x_a = \sum_{r} \sum_{s} \sum_{k} f_{rs}^{k} c_{a,k}^{rs} \]

Among them: \( q_{rs} \)—OD traffic volume between origin and destination; \( x_a \)—Traffic flow on the road section; \( t_a(w) \)—Travel time; \( t_s \)—Traffic resistance.

2.2. Traffic Assignment Algorithm
In the traditional FW algorithm, the update of the flow is the core strategy, but the initialization and update of the section flow are all-or-nothing allocation methods. The focus of this algorithm is to find the shortest path, so when the FW algorithm is performed, it is very cumbersome to search for each OD pair separately. In order to make up for its shortcomings, the following improvement strategy is implemented: if there is only one path between the OD pair, then the update of its traffic is ignored; If the distribution result of the flow between the OD pairs cannot make the objective function drop, then the update of its search step and flow is ignored[4].

The network diagram shown in Figure 1 is used for testing. The network has 13 nodes, 19 road sections, and 4 OD pairs. The basic parameters of the network are shown in Table 1 and Table 2:

Figure 1. Test network diagram
Table 1. Road network parameters

| Road section | Free flow time (min) | Capacity (vehicles/h) |
|--------------|---------------------|-----------------------|
| 1            | 15                  | 1200                  |
| 2            | 10                  | 800                   |
| 3            | 8                   | 750                   |
| 4            | 8                   | 750                   |
| 5            | 10                  | 800                   |
| 6            | 8                   | 800                   |
| 7            | 15                  | 1200                  |
| 8            | 10                  | 800                   |
| 9            | 10                  | 750                   |
| 10           | 8                   | 750                   |
| 11           | 12                  | 1000                  |
| 12           | 10                  | 800                   |
| 13           | 12                  | 850                   |
| 14           | 12                  | 800                   |
| 15           | 10                  | 800                   |
| 16           | 5                   | 600                   |
| 17           | 15                  | 750                   |
| 18           | 10                  | 1000                  |
| 19           | 5                   | 750                   |

Table 2. OD demand table

| OD  | Traffic demand (vehicles/hour) |
|-----|--------------------------------|
| 1-2 | 1500                          |
| 1-3 | 1200                          |
| 4-2 | 1000                          |
| 4-3 | 1400                          |

Write a C language program to calculate the objective function value of FW and improved FW algorithm after each iteration. The iteration number and running time of the two algorithms are shown in Table 3, and the comparison of the iterative objective function values of the two algorithms is shown in Figure 2.

Table 3. Number of iterations and running time of the two algorithms

| Number of iterations | FW algorithm10^7 | Improved FW algorithm10^7 |
|----------------------|------------------|---------------------------|
| 0                    | 45.97            | 41.97                     |
| 1                    | 43.01            | 38.26                     |
| 2                    | 40.84            | 37.03                     |
| 3                    | 39.05            | 36.45                     |
| 4                    | 37.48            | 36.08                     |
| 5                    | 37.08            | 36.07                     |
| 9                    | 36.45            |                            |
| 10                   | 36.23            |                            |
| 18                   | 36.13            |                            |
| 19                   | 36.10            |                            |
| 20                   | 36.08            |                            |
| 21                   | 36.07            |                            |
| operation hours(s)   | 47.05            | 20.32                     |
Figure 2. Comparison of the iterative objective function values of the two algorithms

It can be seen from the figure that the improved FW algorithm can provide a better initial solution, and the number of iterations and convergence time required to achieve convergence are significantly less than the FW algorithm, so the improved algorithm can save running time and improve operating efficiency. Have very good practicality.

3. Network Storage Structure Based on Traffic Delay at Intersection

Traditionally, there are five network storage structures: adjacency matrix method, adjacency linked list method, arc representation, star representation, and incidence matrix method.

Adjacency matrix method: If there is an arc between two points, then the corresponding element in the adjacency matrix is 1, otherwise it is 0. In the adjacency matrix, the sum of the elements in each column is the in-degree of the corresponding node, and the sum of the elements in each row is the out-degree of the corresponding node.

Adjacent linked list method: nodes are stored in an array, each node corresponds to a chain, and each chain contains all arcs of the point.

Arc notation: List the start and end points of all arcs, and the corresponding weights on the arcs are stored in extra space.

Star notation: A single array is used to store all adjacent points of each node, and an additional array is used to record the starting address of each node's arc.

Incidence matrix: In the incidence matrix, each row corresponds to a node, and each column corresponds to a road section.

Figure 3. Network diagram

For the network diagram shown in Figure 3, the storage structures established by different methods are shown in the following figure.
For node delays, the comprehensive delays are generally allocated to each road section, so that the network can be stored through the previous storage structure, and the shortest path problem can be solved by Dijkstra or the labeling correction method. However, this method is not practical, because the delays of different entrance lanes at intersections are different, and different flow directions of the same entrance lane also have different delay values. In general, turning left is greater than going straight, and going straight is greater than turning right. Therefore, the comprehensive delay allocation method will cause inaccurate results. To consider the impact of flow delays, the first problem to be solved is how to store flow delays, which requires a new data structure. The traditional storage structure is to store the basic parameters of the network, including network nodes, edges and weights, and does not consider the flow delay at the nodes. This paper designs a storage method based on the flow delay for the adjacent linked list method.

It can be seen from Figures 7 and 8 that the vertex field Vertex of the adjacency table stores the content of the vertex, and the pointer field Next is the head pointer of the vertex.

In this paper, a pointer Pointer is added to the adjacency list node structure, which points to a one-dimensional delay array, that is, the delay is taken into account in the storage structure, as shown in Figure 9:

Use an improved storage structure to show the adjacency table in Figure 10. The improved adjacency list structure is shown in Figure 11, where Table 4 shows the flow delay of the node.
The improved adjacency linked list can store the flow direction delay in the structure without considering other information of the node, which greatly saves storage space, improves computing efficiency, and has good practical value.

4. Case Analysis

4.1. Road Network Modeling
This paper adopts the ideal road network and intersection, as shown in Figure 12, simplified the road network to a simple truss structure, and considers the full stress of node 3 as the constraint. Only the delay of No. 3 node is considered, and the right turn delay is not considered. ABCD is only used as a traffic absorption point, not a node. The basic attribute data of the road network is shown in Table 5 and Table 6.
Figure 12. Simplified road network and intersection 3

Table 5. Basic attributes of road network

| Road section | Free flow time(min) | Capacity (vehicles/hour) |
|--------------|---------------------|--------------------------|
| A-1 1-A A-2 2-A | 4                   | 700                      |
| B-1 1-B B-4 4-B | 5                   | 800                      |
| C-2 2-C C-5 5-C | 4                   | 950                      |
| D-5 5-D D-4 4-D | 6                   | 1000                     |
| 1-3 3-1 3-5 5-3 | 5                   | 1400                     |
| 2-3 3-2 3-4 4-3 | 6                   | 1200                     |

Table 6. OD traffic volume

| OD | A-D | D-A | B-C | C-B |
|----|-----|-----|-----|-----|
| Traffic demand (vehicles/hour) | 1000 | 1200 | 900  | 1400 |

4.2. Experimental Results

Use ALEX to solve the model and program calculations. The algorithm loops 9 times to reach convergence. The operation convergence of the algorithm is shown in Figure 13, the flow diagram of each flow direction at the intersection and the operating data are shown in Figure 14 and Table 7.

Figure 13. Number of iterations

Figure 14. Traffic flow in each direction at an intersection

Table 7. Traffic allocation of road sections

| Road section | flow  | Road section | flow  |
|--------------|-------|--------------|-------|
| A-1          | 486.378 | C-2          | 726.722 |
| 1-A          | 600.273 | 2-C          | 453.288 |
| A-2          | 513.622 | C-5          | 673.278 |
| 2-A          | 599.727 | 5-C          | 446.712 |
| B-1          | 457.892 | D-4          | 619.305 |
| 1-B          | 709.391 | 4-D          | 500.891 |
| B-4          | 442.108 | D-5          | 580.695 |
| 4-B          | 690.609 | 5-D          | 499.109 |
From the experimental data, we can see that taking the intersection of node 3 as the full stress constraint, considering the delay of intersection flow, capacity, and signal optimization, the calculated intersection traffic and delay results are within a reasonable range. Not only the road network achieves the goal of balanced distribution, but also the optimal operation state of the intersection, and a more realistic and ideal distribution result is obtained. At the same time, the algorithm has good iterative convergence.

5. Full Text Summary and Outlook
Aiming at the complex relationship between signalized intersection delay, queue length and capacity, this paper establishes a signal optimization model to facilitate better signalized intersection optimization research. The principle of Wardrop balance is studied, the traffic assignment algorithm is analyzed, and the example verification of the improved algorithm is made for the shortcomings of the FW algorithm. The road resistance function in this article is based on the time form. In actual situations, when the driver chooses a route, the impact of road segment travel time and intersection delay time on it is different. This is also the actual distribution of traffic flow and scientific distribution provides a good basis for fitting.

6. References
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