Multi-indicator Road Traffic State Assessment Based on Path State

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Abstract. In order to evaluate the traffic condition of urban road, the article makes an actual modeling of the urban road junctions and the analysis of the status of sub-lanes. Combined with various impedance factors of the road network, in this paper, a state coefficient matrix is used to represent the road network impedance data, and a road traffic status assessment system based on the actual path status with multi-parameter indexes is proposed. The evaluation system is improved based on the existing state assessment methods and breakthroughs in the assessment mode. In the past, it only estimated the overall traffic condition at the intersection; the evaluation method was more efficient and the evaluation result was more accurate. The actual road network in Shijingshan District is used to verify the results. The results show that the algorithm is effective.

Introduction

The assessment of urban traffic status has always been a key issue in the field of transport. The core of this assessment is to accurately determine whether the road is open or congested. With the continuous improvement of the times, the judgment efficiency, the authenticity of the state and the accuracy of the different lane states become more and more important. However, most of the current researches are based on the improvement of the overall state evaluation of the intersection with fuzzy recognition. For different lane states, The number of lanes, the actual path impedance status and other less studied. Liao Xiaoyong proposed a discrete time series analysis method based on Detrended Fluctuation Analysis (DFA), which provided a new channel for revealing the inherent laws of traffic flow through the change of traffic parameters [1]. Shi Yan combined with the release of urban traffic management system information summarizes the road traffic status assessment and information release for urban traffic management [2]. Zhang et al. Proposed the evaluation method based on fuzzy evaluation with multi-index weight method and carried out the congestion prediction analysis based on SVM [3]. Zhang Jianhua and other GPS data collected using real-time road speed assessment [4]. Hao Yong just put forward a kind based on the floating car data multi-car speed fusion algorithm [5].

Algorithm Description

Build the Path State Matrix

We combine the two main road network impedance factors to build the road network, namely: by the section of the road lights with time, vehicle travel time, etc. constitute the cost of time; by the road traffic congestion index characterized by path impedance costs. Both of these can basically cover the set of impedance factors existing in the current road.

The Introduction of Road Impedance Coefficient

We introduce time cost Tc (time cost) and traffic congestion index Tsi (Traffic speed index). The time cost Tc (time cost) is defined as the cost of the time it takes to get the desired destination or service. Which the actual signal road timing and the actual travel time as a basis for the cost of time [6].

Traffic congestion index Tsi (Traffic speed index) a lot of definitions, calculation basis and standards are also different. Here we introduce the traffic speed index Tsi (Traffic speed index),
which is used to reflect the degree of traffic jam caused by different widths and maintenance degrees of different lanes. A speed-based traffic index algorithm model is constructed:

\[ T_{si} = \left[ 1 - \frac{\sum_{i=1}^{j} k_{ij} (V_i / V_{\text{fr}})}{\sum_{i=1}^{j} k_{ij}} \right] \times 100 \]  

(1)

Where \( V_i \) is the travel speed of the road section, \( l_i \) is the length of the road section, \( k_i \) is the number of lanes of the road section, \( V_{\text{fr}} \) is the reference speed of the road network of different grades = \( \min \{ \max \{ \text{road design speed, research maximum speed, lane limit speed} \} \} \).

Finally, the definition \( S \) is the impedance coefficient of every road segment in the road network. Obviously the impedance coefficient of the road segment is obtained from the above two indices \( T_c \) and \( T_{si} \), then the average of the two indicators is taken as:

\[ S = \frac{T_c + T_{si}}{2} \]  

(2)

In a crossroads, by the straight line, turn left, turn right and so there are several paths, each path has its corresponding path impedance coefficient, for an intersection, each road entrance and exit of the road. There are direct, turn left and right turn these three path states, a total of six path states, and a classic intersection of the local road network has four entrances and four exit road, we can define its path state matrix is an \( mn \)-th order matrix, and the element in the jth column of the ith row in the matrix is defined as the impedance coefficient \( S_{ij} \) of the path from path i to path j. Take a typical intersection of local road network as an example, there are four import road, each import road left, right and right of these three states, the path state matrix is the following matrix:

\[
\begin{pmatrix}
S_{11} & S_{12} & S_{13} & S_{14} \\
S_{21} & S_{22} & S_{23} & S_{24} \\
S_{31} & S_{32} & S_{33} & S_{34}
\end{pmatrix}
\]

(3)

In the process of traffic status assessment, we can use the path state matrix to combine the algorithm function and the path state matrix, so that the state evaluation process combines various impedance factors of the actual path to ensure the authenticity of the path finding result.[7]

Algorithm Ideas

In real life, the same thing or phenomenon often has multiple attributes. Therefore, in recognizing things or phenomena, it is necessary to take all factors into account. That is, multi-factor pattern recognition is adopted. In the multi-factor pattern recognition, the first set of factors set U, and then set up a standard set of factors on the fuzzy model library[8]. Described in fuzzy mathematics as follows: Let U have n fuzzy subsets in the domain \( A_1, A_2, \ldots, A_n \), Constitute a standard model library \( \{A_1, A_2, \ldots, A_n\} \), Each fuzzy model \( A_i (i = 1, 2, \ldots, n) \) is characterized by m features on U. Then \( A_i \) is a fuzzy vector: \( A_i = (A_{i1}, A_{i2}, \ldots, A_{in}) \), Then a set of fuzzy vector A is formed by n fuzzy subsets \( A_1, A_2, \ldots, A_n \). It is a matrix of M rows and N columns, also known as fuzzy comprehensive evaluation matrix, denoted as \( R(u_i) \), Fuzzy comprehensive evaluation matrix R can also be considered as a single factor evaluation vector \( R_j (j = 1, 2, \ldots, m) \) composition. In this way, a total evaluation matrix is constructed from m single-factor evaluation vectors \( R_j \).
Since \( X \) is a normal vector, we need to introduce the membership vector of general vector \( x \) to fuzzy vector set family \( A \).

**Definition:** Let \( X = \{p_1/ x_1, p_2/ x_2, ..., p_m/ x_m\} \) be a membership function on the domain \( U \) (set of factors), simply using the vector \( X = \{p_1, p_2, ..., p_m\} \) to represent it, then the vector \( Y = X_{\infty} \) is the result of \( X \) by fuzzy transformation, which represents a membership function on the domain \( V \) (comment set).

\[
Y = (q_1/ y_1, q_2/ y_2, ..., q_n/ y_n)
\]

(5)

\[
q_i = \sum_{j=1}^{m} \mu_{ij} \cdot p_j \quad \{i = 1, 2, \ldots, n\}
\]

(6)

\( \theta \) and \( \cdot \) represent two kinds of operations, so that the integrated function can be taken as the following two forms.

1. Let \( \theta = \sum \), that is addition; \( \cdot = \ast \) that is multiplication, the transformation formula is:

\[
q_i = \sum_{j=1}^{m} \mu_{ij} \ast p_j \quad \{i = 1, 2, \ldots, n\}
\]

(7)

2. \( \theta = \text{max} \) is great, \( \cdot = \text{min} \) is minimal, the transformation formula is:

\[
q_i = \sum_{j=1}^{m} \mu_{ij} \ast p_j \quad \{i = 1, 2, \ldots, n\}
\]

(8)

Taking a calculation method, we can finally get a membership function in the universe \( Y = (q_1/ y_1, q_2/ y_2, ..., q_n/ y_n) \).

If \( q_i = \max \{q_1, q_2, ..., q_n\} \ \{i = 1, 2, \ldots, n\} \), according to the principle of maximum membership, the pattern is relatively subordinate to pattern \( y_i \).

Based on the analysis of the traffic flow characteristics of urban road traffic conditions, the membership function of each fuzzy set of speed, occupancy, and parking delay is constructed. \[9\]

\[
\begin{align*}
0 & \quad \text{if } x < a_i \\
\frac{x-a_i}{(b_i-a_i)} & \quad \text{if } a_i \leq x \leq b_i \\
1 & \quad \text{if } x > b_i \\
(i = S; j = S) & \text{or } (i = K; j = \Phi) \\
1 & \quad \text{if } x < a_i \\
\frac{b_i-x}{(b_i-a_i)} & \quad \text{if } a_i \leq x \leq b_i \\
0 & \quad \text{if } x > b_i \\
(i = S; j = O; D) & \text{or } (i = K; j = \Phi)
\end{align*}
\]

(9)

\[
\begin{align*}
0 & \quad \text{if } x < a_i \\
\frac{x-a_i}{(b_i-a_i)} & \quad \text{if } a_i \leq x \leq b_i \\
1 & \quad \text{if } x > b_i \\
(i = N; i = C; j = S, O, D) \\
\end{align*}
\]

(10)

\[
\begin{align*}
0 & \quad \text{if } x < a_i \\
\frac{x-a_i}{(b_i-a_i)} & \quad \text{if } b_i \leq x \leq c_i \\
1 & \quad \text{if } x > c_i \\
(i = N; C; j = S, O, D)
\end{align*}
\]

(11)

Where: \( a_{ij}, \ b_{ij}, \ c_{ij}, \ d_{ij} \) are parameters to be evaluated.
**Algorithm Validation**

On the Windows XP operating system platform of virtual machine, using VB programming language combined with map software MAPX and VB 6.0, a set of urban traffic status assessment system was developed to load the real road network of GIS map in Beijing. After selecting Lotus Pond West Road and Jinjiaocun Bridge Intersection network as an experimental object, respectively, according to the classical parameter-based fuzzy identification evaluation model, based on the path state matrix multi-indicator traffic status evaluation model for the state of the intersection of the state assessment.

**Use the Classical Fuzzy Recognition Evaluation Model for State Assessment**

Based on the existing software for building floating vehicles, we use the classic fuzzy recognition assessment model to intercept the lotus pond west road in Beijing on March 7, 2017 at the evening peak time of 17: 30-18: 30 and the time interval of 5 minutes The average travel speed of the west section of the Lotus Pond from west to east is left and the intersection of the left and right is the estimated average delay of the two traffic parameters, as shown in the following table 1.

<table>
<thead>
<tr>
<th>Time period</th>
<th>Average journey speed (KM/h)</th>
<th>Turn left at the intersection of the average trip delay (s)</th>
<th>Turn right at the intersection for average trip delays (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17:30-17:35</td>
<td>20.6</td>
<td>80.1</td>
<td>44.5</td>
</tr>
<tr>
<td>17:35-17:40</td>
<td>21.3</td>
<td>76.5</td>
<td>42.5</td>
</tr>
<tr>
<td>17:40-17:45</td>
<td>18.3</td>
<td>88</td>
<td>52</td>
</tr>
<tr>
<td>17:45-17:50</td>
<td>10.9</td>
<td>94.2</td>
<td>60.3</td>
</tr>
<tr>
<td>17:50-17:55</td>
<td>15.2</td>
<td>94.4</td>
<td>63.3</td>
</tr>
<tr>
<td>17:55-18:00</td>
<td>20.9</td>
<td>78.4</td>
<td>44.7</td>
</tr>
</tbody>
</table>

Table 1. Estimated value of traffic parameters from south to north of Lotus Pond West Road.

According to the average speed of the main road link membership function and intersection membership function, to determine the link and intersection of the evaluation set (Unblocked state, general congested state, severe congested state). The membership results of the judgments are shown in the table 2.

<table>
<thead>
<tr>
<th>Time period</th>
<th>Smooth</th>
<th>General congestion</th>
<th>Serious congestion</th>
<th>Smooth</th>
<th>General congestion</th>
<th>Serious congestion</th>
<th>Smooth</th>
<th>General congestion</th>
<th>Serious congestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>17:30-1 7:35</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.7</td>
<td>0.3</td>
<td>0</td>
</tr>
<tr>
<td>17:35-1 7:40</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0.23</td>
<td>0.77</td>
<td>0.83</td>
<td>0.17</td>
<td>0</td>
</tr>
<tr>
<td>17:40-1 7:45</td>
<td>0</td>
<td>0.77</td>
<td>0.23</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.2</td>
<td>0.8</td>
<td>0</td>
</tr>
<tr>
<td>17:45-1 7:50</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>17:50-1 7:55</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>17:55-1 8:00</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0.1</td>
<td>0.9</td>
<td>0.69</td>
<td>0.31</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2. Lotus Pond West Road - traffic parameters under the degree.
Multi-indicator Traffic State Evaluation Model Based on Path State Matrix

Similarly, we use the multi-indicator traffic status evaluation model based on the path state matrix to evaluate. Compared with the previous method, we consider the real-time interference due to the impedance factors such as the signal period, the actual lane width and the lane maintenance degree. The traffic parameters of straight-ahead, left-turn and right-turn are analyzed by using different evaluation indexes. According to the average speed membership function of the road section and membership function of intersection (unblocked state, general congested state, severe congested state), the membership results of the judgments are shown in the following table 3.

Table 3. Lotus Pond West Road - traffic parameters under the degree.

<table>
<thead>
<tr>
<th>Time period</th>
<th>Straight road</th>
<th>Turn left at the intersection</th>
<th>Turn right at the intersection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Smooth</td>
<td>General congestion</td>
<td>Serious congestion</td>
</tr>
<tr>
<td>17:30-17:35</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>17:35-17:40</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>17:40-17:45</td>
<td>0</td>
<td>0.77</td>
<td>0.23</td>
</tr>
<tr>
<td>17:45-17:50</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>17:50-17:55</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>17:55-18:00</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

We use the Matlab to perform the fitting and stability analysis on the data of the degree of membership calculated by the two methods, and select the 15 continuous membership values of the general congestion blocked by the two methods as the contrast objects to observe the characteristics...
of the data obtained by our two methods. It can be seen from the figure below that the degree of membership of traffic parameters obtained by the method reported in this paper is more in line with the real situation, with less fluctuation, with a gradual and continuous characteristic and more stable, While the classical fuzzy evaluation method has a mutation point of inflection point is more, in statistics should belong to the drift of abnormal data, this data should be removed, so the error is greater, the accuracy of the state assessment of influences.

Summary and Outlook

Based on the original research on urban state assessment, this paper first considers the existing impedance factors such as time cost, lane width and degree of maintenance, and introduces the path state matrix to make the algorithm more realistic and reliable. Combined with the classical fuzzy evaluation algorithm, the multi-parameter evaluation method is improved and perfected. By means of the experimental platform and the actual GPS data, the traffic status is evaluated by two methods respectively. The results are studied and compared analysis, come to the evaluation method of this article more real and accurate with great practical value.

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