Method of Node Importance Measurement in Urban Road Network

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ABSTRACT. The node importance measurement plays an important role in analyzing the reliability of the urban road network. In this thesis, the topological structure, geographic information and traffic flow characteristics of urban road network are all considered, and methods of node importance measurement of urban road network are proposed based on a spatially weighted degree model and h-index from different perspectives. Experiments are given to show the efficiency and practicability of the proposed methods.

KEYWORDS： Urban road network; node importance; spatially weighted degree; the Hansen Index; h-index

1 Introduction

The urban road network can be abstracted into a connected graph composed of nodes and edges. Node is an important unit of network connectivity system.to find out the important ‘core nodes’ in the road network, the key is to explore the method of quantifying the importance of the nodes, namely, to study the important measurement methods of nodes. So it is necessary through the research of methods of node important degree, it is concluded that an effective method to measure the importance of nodes, and then find out the important node of city road network, focus on to them, to strengthen protection and management, to improve the reliability of urban road network, urban traffic safety and effective operation.

Node degree only considers the node information about themselves, cantona, etc on the basis of considering the information of neighbor nodes, think the importance of nodes is proportional to the node and its neighbor node degree of the two.The indicators based on the global attribute of the network are involved Betweeness centrality,Closeness centrality and eigenvector centrality.Index based on network location attribute. Kitsak (2010) etal. proposed the indicator of the position of the node in the network -- k-shell.

2 Node importance measurement based on spatial weighting

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2.1Spatial weighted model

N.Wan [2] proposed a space-weighted node degree model considering the road grade and the length of the road..The space weighted model can be expressed as:

$$N_d^i = \sum_{t=1}^{ec} c_t \left(1 + \omega \frac{l_t - l_{\min}}{l_{\max} - l_{\min}} \right) \tag{1}$$

ec is the number of edges connecting nodes i, c_t is the level of the first link to which the node i is connected, l_t is the length of the first link t to which the node i is connected, $l_{\min}$ and $l_{\max}$ are the minimum and maximum length of all links in the entire network, ω is the weight coefficient for the importance of link length in a particular area.

2.2 The improvement of space-weighted model

Improvement method

Traffic congestion is easily caused by the small number of lanes Therefore, in the urban road network, the number of lanes has a significant impact on node importance. Based on the N.Wan model, this paper considers the influence of the number of lanes on the node importance and proposes an improved space weighted (ISWD) model, which can be expressed as:

$$k_d^i = C_d^i + \sum_{t=1}^{ec} c_t \left(\omega_1 \frac{l_t - l_{\min}}{l_{\max} - l_{\min}} + \omega_2 \frac{n_t - n_{\min}}{n_{\max} - n_{\min}} \right) \tag{2}$$

C_d^i is the traditional method of determining the node degree, c_t is the level which node i connected to the road t, n_t is the number of lanes which node i connected to the road t, ω_1 is the section length importance weight coefficient, ω_2 is the lane number importance weight coefficient, $\omega_1 + \omega_2 = 1$.

Evaluation criteria

In this paper, we use sequence difference DF to evaluate the performance of node importance measure method. The difference between the two sequences is expressed as:

$$DF(X, Y) = \frac{\sum_{i=1}^{n} (x_i - y_i)^2}{n} \tag{3}$$

X, Y are the given sequences, x_i, y_i are the sequence

$$Sum(X) = \sum_{j}^{m} DF(X, Y_j) \tag{4}$$

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m is the sequence number, Y_j is the sequence which number is j.

3 H-index based node importance measurement method

3.1 Road Network node traffic flow correlation analysis theory

Due to the connectivity of the urban road network, there is often a relationship of different intensities between the traffic flows at the intersection of road networks [5].

Data preprocessing

There are some problems in the data transmission such as errors and manual operation errors, the traffic flow data acquired from the detectors will be lacking, invalid, wrong and inaccurate, so it is necessary to carry out some pre-deal with.

Network node correlation coefficient

(1)Establish the original traffic flow matrix between intersections:

(2)Data normalization

(3)find the correlation coefficient matrix

Section cited coefficient

$$h_{ij} = \left[(r_{ij} - \min r_{ij}) \div \frac{1 - \min r_{ij}}{m} \right] \tag{5}$$

h_{ij} is the section index for node i and node j. r_{ij} is the correlation coefficient between intersections,m is the number of intersections.Then we can get the node index matrix H between nodes:

$$H = \left(h_{ij} \right)_{m \times m} \tag{6}$$

3.2 Methods for calculating the importance of urban road network node based on h index

Firstly define the index h_r and index g_r of the node.

$$h_r^i = \max(k) : c_k^i \geq k \tag{7}$$

$$g_r^i = \max(k) : \sum_k c_k^i \geq k^2 \tag{8}$$

Evaluation criteria

(1) intersection degree

$$Sim(X,Y,k) = \frac{\text{card}(X \cap Y)}{k} = \frac{\text{card}\left(top_i^k \cap top_j^k\right)}{k} \tag{9}$$

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(2) intersection value

$$rank_i^k|(X \bigcap Y) = \frac{\sum_{v \subset X \bigcap Y} sequ_i^v}{\mathrm{card}(X \bigcap Y)} \tag{10}$$

4 Case analysis

This section chooses the importance of the regional research road network nodes within the scope of Shuiyangjiang Avenue in As shown in FIG. 1.

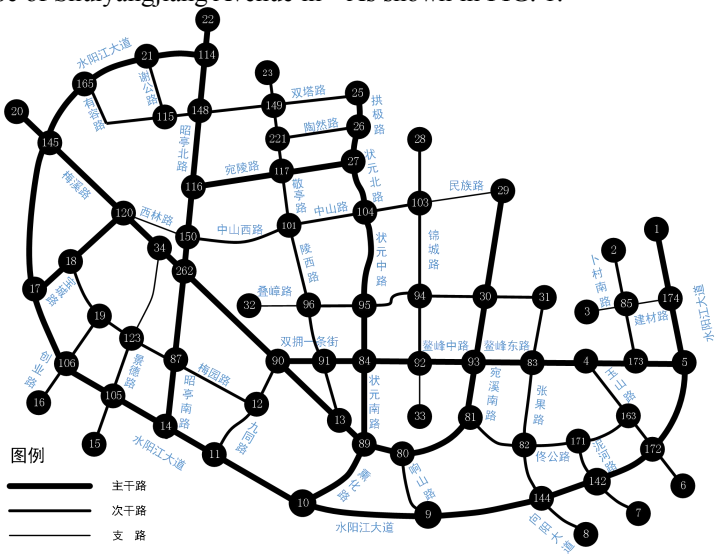

Fig1 The road network topology diagram within the confines of Shuiyangjiang Road

Table1 Traffic volume table of lanes in intersection

Name	Type	Remarks
SSID	VARCHAR2(30)	Mount ID
CDBH	NUMBER(2)	Lane number
BEGINTIME	DATE	Statistics start time
ENDTIME	DATE	Statistics end time
Flow	NUMBER (5)	The number of vehicles counted in five minutes

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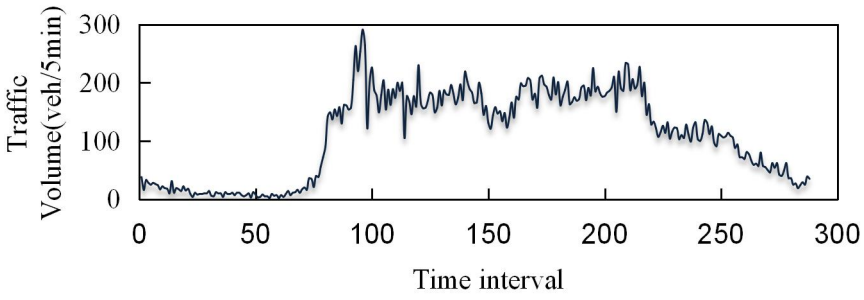
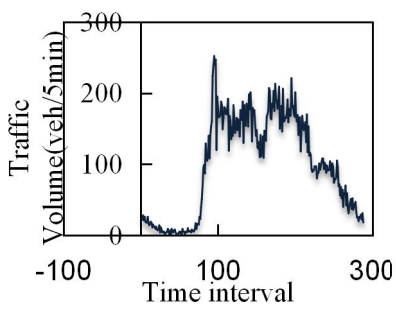
4.1 Network node traffic flow correlation analysis

(1) data preprocessing

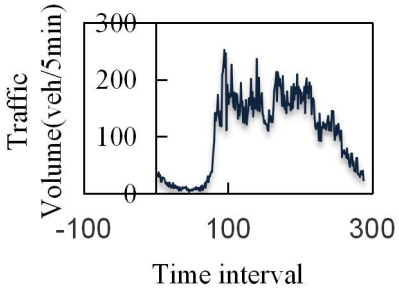
The traffic data of 3 different road network nodes are selected and their traffic flow statistics are plotted as shown in FIG. 2.



a）HK-90



b）HK-91



c）HK-84

Fig. 2 The traffic flow sequence of three intersections

4.2 Based on the h index node importance measurement results

h_r , g_r are shown in table 3.Calculate the intersection of the first ten nodes of the two sorted sequences and intersection values $rank$ are as follows:

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$Sim\left(top_{h_r}^{10}, top_{g_r}^{10}\right) = 0.6$, $rank_{h_r}^{10} \left| \left(top_{h_r}^{10}, top_{g_r}^{10}\right) = 2.33 \right.$, $rank_{g_r}^{10} \left| \left(top_{h_r}^{10}, top_{g_r}^{10}\right) = 1.83 \right.$,

$\Delta rank(h_r, g_r, 10) = 2.33 - 1.83 = 0.5 < 0$,Because of this, nodes based on g_r exponential identification are more important.

Table 3 h_r index and g_r index of nodes

Node number	h_r	Sort	g_r	Sort
HK-101	29	3	32	2
HK-103	27	19	30	20
HK-104	28	12	32	2
		.....		
HK-94	25	30	30	20
HK-95	25	30	30	20
HK-96	27	19	31	10

5 Conclusion

1) An improved spatial weighted model is proposed for the study of the importance of urban road network nodes. This flexibility makes the model suitable for different types of spatial networks.

2)Propose a method to calculate the importance degree of urban road network node based on Hansen index.

3)Propose the method of calculating the degree of importance of city road network node based on h index - index and index.

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