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AN IDENTIFICATION METHOD FOR THE HUB NODE OF URBAN TRANSPORT NETWORK BASED ON THE LOCAL MODULARITY

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ABSTRACT

It is a major scientific theoretical significance and practical value that the identification of the hub node in the transport network. This paper presents a new method which can detect the hub node of the urban transportation based on the idea of local modularity measure. Evaluation indicators include node degree, clustering coefficient, peak hour traffic flow. First, apply a complex network of local modularity Societies division method. Second, looking for societies where the node with the largest peak-hour traffic flow .Last, identify the hub nodes in the transport network. Since the algorithm is reflected from the static and dynamic characteristics of the transport network node, it is the Hub node identification in the transport network that is a high degree of accuracy. Through the surrounding junctions along the Chang'an Avenue in Beijing as an example, verify the feasibility of the method.

Keywords: *Complex Networks, Urban Transport Network, HUB node , Local Modularity*

1. INTRODUCTION

The rapid increase of urban population and private cars cause a higher demand for transport, but the backward transport system has become the main aspect of the constraints of sustainable urban development. Traffic bottlenecks affecting the smooth flow of traffic is a very important factor.The selection of Hub nodes in the transport network is significant for the stability of the network structure and the control effectiveness.

With the rapid development of network size and the computer technology , complex network becomes a new research direction. It became a hot topic of national scientists and research institutions that using the theories of complex networks on the complexity research of the urban traffic network to explore the internal mechanism of urban traffic congestion and identification problem of the transportation network Hub node. Latora[1] group proposed the method that using the concept of validity to look for the key component of the network , And study the effective performance of the Boston subway network . Daganzo[2] put forward the CTM , and the further expansion of CTM, used to solve multiple intersection situation; Given intersection merger and divergent flow evolution formula . Lo and Szeto[3]structure dynamic traffic assignment DTA model , the model can capture some simple characteristics of the traffic jams and the spread . According to Scale-free property based on the public transport network, combined with the theories and methods of public transport network equilibrium assignment, GAO Zi YOU[4] and others put forward the method looking for network distribution point for the program, the method can handle the signal network as well as sections of congestion.

In this paper, the network of urban transportation system is the research object, thinking based on the complex network of local modularity, node degree, clustering coefficient, peak hour traffic flow based on use of complex network community divided by looking for with the greatest societies where peak hour traffic flow node, and then identify the transportation network Hub node, and thus lay the theoretical foundation for the effective mitigation and prevention of traffic congestion

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2. PRELIMINARIES

Urban traffic network is a typical network that constituted by the points and edges , it is a combination of the physical network from the road and traffic demand network, including road that can be abstracted as connection, road intersections abstract nodes, a large number of points and edges constitute cities transportation network architecture.

2.1 The Hub Node In Transportation Network

Hub nodes in a scale-free network are the tail point of degree segment, that the greater degree node, also known as the central node or hub node of these nodes, play an important role in maintaining the functionality of the network.

It is a theoretical problem that finds Hub nodes in transportation network. Because it is not necessarily the node with the largest number of edges but plays a key role in the entire network node. The determination of Hub node in the urban transport network is not only conducive to the prevention of the intentional attack, but also contributes to the transportation network design problems.

2.2Node Values Of The Integrated Feature

$G(V,E)$ represents an urban transport network, where $V=\{v_i \mid i=1,\cdots,N\}$ is the set of vertices, $E \subset \{(v_i,v_j) \mid v_i,v_j \in V\}$ is the set of edges, define the following network characteristics:

Definition 1: Node degree: refers to the other nodes in the node associated with the number of edges.

Make a collection of nodes $V=\{v_1,v_2,\ldots,v_N\}$, so disorder even in pairs (v_i,v_j) ,it expresses the edge that between $v_i \in V$ and $v_j \in V$ is a collection of V node set, $E \subset \{(v_i,v_j): v_i,v_j \in V\}$ that the edge set of graph, the degree D_i of v_i node ,that is connectivity to other nodes in the node number, D_i expressed as:

$D_i = |\{ (v_i, v_j) : (v_i,v_j) \in E, v_i,v_j \in V\}|$

Definition 2: Clustering Coefficient: It is the proportion that neighbors of the node with the node connected to the interconnection .For example: the network of relationships in your friends, your two friends are also friends with each other, which is like that. This property is called the network's clustering features.

General, assuming a network node i has edges to it and other nodes connected to this node is called neighbors of node i. Clearly, in these nodes k_i may have up to $k_i(k_i-1)/2$ edges. And there are so many nodes k_i between the actual number of edges Ei and the total possible number of edges $k_i(k_i-1)/2$ is defined as a ratio of the clustering coefficient of node i , E_i , that is $C_i = 2E_i(k_i-1)/2$, （1）

Definition 3: Peak hour traffic flow S： the amount of movement that the node peak hours within the unit time, the peak-hour traffic reflects the carrying capacity of the transport network node on the network traffic flow

In the complex network ,the nodes as cluster centers have a strong connection strength not only with other similar nodes but also between nodes connected to each other with greater density and strength of connections, that has a strong local clustering. Calculate the value of each node of the integrated features, the integrated features CF_i of each node can be calculated by the node degree , clustering coefficient values and Peak hour traffic flow S.

$$CF_i = \{\alpha C_i + (1-\alpha) D_i / N\} * S_i \ , \quad (2)$$

α is a parameter adjustable, 0< α <1, N is the number of nodes in the network.

Category of the urban transport network node is divided into key nodes, Hub nodes, important nodes ,associated nodes and isolated nodes. The mean that society includes the Hub node is the largest peak hour traffic mean. Mean Societies peak hour traffic can be used to find the key associations

$$S_j = \frac{\sum_{m=0}^{k} S_m}{k} \ , \quad (3)$$

S_j is the mean of Societies peak hour traffic, $0<m<k$, k is the number of nodes in the association, j is the number of divided societies

2.3Local Modularity

In complex networks, Clauset introduced the idea of local modularity, not only has good clustering results, but also greatly reduces the time complexity of the algorithm.

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In the literature 6, Local Module is defined as

$$Q = \frac{L_{in}}{L_{in} + L_{out}}, \qquad (4)$$

Suppose that L_{in} node belongs to the association, within the community the number of edges connected to the node. L_{out} node belongs to the society, the number of edges between community external nodes and internal nodes connected to the node . The main idea of this algorithm is a candidate on each node v_k assuming nod v_k belongs to community C, calculate the corresponding value of the local modularity. The node that maximum degree of local modules into societies C, then updated set of candidate nodes, Until no further increase in Q values, the society has been formed, repeat the above steps. Until all nodes in the network have the ownership of the community, the community structure of the corresponding point on the network that is the actual community structure.

In this paper, the largest feature value of an integrated node is the initial node in the urban transport network. Point set B said connecting edges point C text will be sub-network node is divided into three parts in Figure (1), the set of points C, B, U, point set C is a collection of nodes that have been identified to belong to the community; and a collection of nodes that is not incorporated into any Societies; U represents a set of points with the point C, without connection to a collection of the point of the edge; the point Set B compared with the Societies candidate collection.

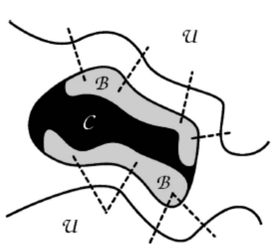

Fig.1: The Division In The Form Of Network Nodes

3. IDENTIFICATION METHOD FOR THE HUB NODE OF THE URBAN TRANSPORT NETWORK BASED ON THE LOCAL MODULARITY

In this paper, the network of urban transportation system is the research object, thinking based on the complex network of local modularity[5], node degree, clustering coefficient[6], peak hour traffic flow based on use of complex network community divided by looking for with the greatest societies, the largest feature value of an integrated node is the initial node. Paper will be divided into three parts as shown in Figure 1 that the set of points C, B, U, C is the set of points which have been identified set of nodes belonging to the society. Set of points B is C of the points that are connected to the side and did not merge the set of nodes of any society; Set of points U is C in the point that no set of connected edge points; Point set B was a candidate set of associations. First, the largest Comprehensive Feature[8] value of an integrated node is the initial node, find the corresponding candidate node which reaches the maximum value of the local modularity Q in the candidate set, merge the node into the community , until no further increase in the Q to update the candidate set , at this point the formation of the community. Second, find the next corresponding candidate node which reaches the maximum value of the local modularity Q but it isn't merged in the candidate, repeat the above steps, until all nodes have the ownership of the community. Finally, calculate the society that corresponding maximum peak-hour traffic[10] mean, Node of the society is the Hub node of the transportation network . End of the algorithm. In the urban transport network, the Hub node identification method based on local modularity is as follows:

Step1：Initialization.

Enter the network data, each node on the network is stored in a linear dynamic list T, the structure of T is as follows: According to the formula(1) (2), Compute the integrated features values of the node , The information of each node will be mapped to the linked list, Label that each node of the community is set to 0.

Node	Degree D	Clustering coefficient C
Peak hour traffic flow S	Comprehensive Features value CF	

Step2：Select the initial node[6].

The integrated Characteristics value of each node is sorted, the queue is formed by descending order. Select the new initial point of. Community from the queue in order CF value and Community label 0 .The Community label of initial node c is named w, indicates that the node v_i belongs to Community w. The local module q_c is set to 0.

Step3：Determine the candidate set.

The node that it connects with C_w and its Community label is 0 in the table T stores the node

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set B. If Communities label isn't 0, proceed to step 6.

Step4：The formation of community structure

For each node v_k of Candidate set B, assuming the node v_k belongs to the community C_w ,then computes Modularity q_k of C_w by applying the formula $q_k = \frac{L_{in}}{L_{in} + L_{out}}$ .To reduce the complexity of the algorithm, this article provides that if q_k less than q_c , then remove v_k from B . By calculation, the greatest degree of module q_k is acquired. If q_k is greater than q_c , then update the value of q_c , and the corresponding node v_k of the q_k is merged into the community C_w ,the corresponding community label is modified to w . If q_k is less than q_c , then perform steps 6.

Step5：Repeat steps 3, 4.

Step6：Get community w .

Step7：Repeat steps 2,3,4,5,6.

Step8：Obtain Clustering results .

Step9: application of the formula (3) associations to find $Max(S_j)$,the node of the society within the transport network is the Hub node.

Create a dynamic list of the time complexity $O(d)$, d is the sum of the internal nodes degree of community. Determining the candidate set and building the community structure are the same time complexity $O(d^2 n)$, n is the number of internal nodes for the community. The time complexity of building a community is $O(d + d^2 n)$, so the time complexity that the whole complex network form all community is $O(D + D^2 N)$, D is the sum of all nodes degree, N is the number of nodes, The time complexity of computing S_j is $O(M)$, M is the community number, the entire time complexity of the algorithm is $O(D + D^2 N + M)$,the time complexity can be simplified to $O(D^2 N)$.

4. SIMULATION ANALYSIS

Figure 2 is the traffic topology diagram of the Chang'an Avenue in Beijing, nodes represent intersection, edges represent sections.

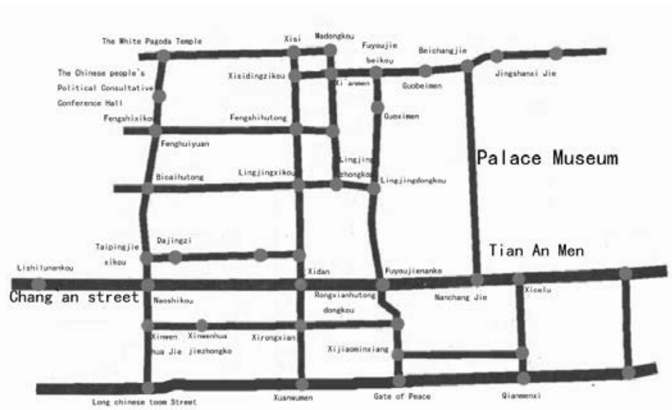

Fig. 2: The Traffic Topology Diagram Of The Chang'an Avenue

Degree node D, node clustering coefficient C, peak hour intersection traffic S values calculated based on the measured data provided by the Beijing Municipal Traffic Management , S is 0.7, CF is calculated by the formula $C_i = \{\alpha C_i + (1-\alpha) D_i / N\} * S_i$, such as shown in Table1 .

Table 1 can get the following information, CF of node Lingjingzhongkou is 371.1764 ,it is the max CF of the table ,so node Lingjingzhongkou is the initial node. First ,establish the candidate set B, B={Lingjingxikou 、 Lingjingdongkou 、 Xi`anmen},apply the formula (4) in B .find the maximum node of the local module and merge the node into community 1, update B , get the value of local module degree Q is 0.4012 , At this point no further increase in Q value, an optimal community, and Community label 1. In the Community label 0, select the largest CF value node, in this example, it is node Juntaibaihuodong. Similarly, Q value will not increase to 0.5099, and Community label 2.Now we have got 2 community. Finally, we get four Societies, calculating the mean S_j in the societies, $Max(S_j)$ is 3831, S_j is the Hub node of transportation network .The Hub transport network node are Chuangchunjieluko, Xuanwumen, Fuyoujienankou, Lingjingzhongkou, this is consistent with the selection criteria that importance of the actual control system nodes.

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Table 1.Transport Network Node Dynamically Linked List

Node	Degree	Peak hourflow	Clustering Coefficient	Comprehensive Features value
Juntaibaihuodong	3	1930	0.23	354.155
Jingshanxijie	3	1515	0.0732	111.7161
Xisidingzikou	3	1500	0.0209	55.695
Bicaihutong	4	2875	0.0395	165.7438
Xinwenhuajie	3	2765	0.0232	107.1161
Juntaibaihuoxinan	2	2390	0.0058	45.5534
Xijiaominxiang	3	885	0.0116	27.0987
Fuyoujiebeikou	3	2470	0.0859	204.0961
GreatHallofthepeople	3	265	0.1719	37.84995
Jingshandongjie	3	2465	0.0023	59.43115
Taipingjiexikou	3	2450	0.0395	122.8675
TCPCCH	2	2920	0.0267	98.3748
Lingjingxikou	4	3345	0.0546	228.1959
Xuanwumen	4	2990	0.0093	109.1649
Lingjingdongkou	3	1700	0.0348	79.662
Fengshengdongkou	3	1530	0.0209	56.8089
Guoximen	2	1970	0.0174	53.5446
Guobeimen	2	2430	0.0662	149.0562
Xicelu	3	680	0.0976	61.7576
Dongcelu	4	390	0.0023	12.3279
Beichangjie	3	2400	0.0883	202.344
Nanchangjie	3	2875	0.0813	228.3038
Rongxianhutongdongkou	3	800	0.0325	36.2
Madongkou	3	1180	0.0035	29.441
Xiwenhuajiezhongkou	2	1540	0.0221	46.9238
Gangwashilukou	4	2860	0.0685	222.937
Naoshikou	4	2915	0.0197	127.6479
Fengshengxikou	4	2930	0.0465	183.2715
Dajingzi	2	2390	0.029	84.367
Xidan	4	2676	0.043	160.8276
Xirongxian	4	1375	0.0453	84.85125
Fuyoujienankou	4	4530	0.108	478.368
Xianmen	4	2695	0.1243	315.342
Qianmendong	4	3080	0.0023	97.3588
Qianmenxi	4	3590	0.0256	172.0328
Lingjingzhongkou	3	2660	0.1672	371.1764
TheWhitePagodaTemple	4	2145	0.0267	104.4401
Changchunjielukou	4	5145	0.0209	229.6214
Xisi	4	2460	0.0372	137.8584
Gateofpeace	4	4465	0.0186	192.0843

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We compare the proposed algorithm with the algorithm CPM,FCM. The experimental results are given in Figure 3, y-axis represents a clustering accuracy of the algorithm, x-axis represents the number of iterations of the algorithm. As can be seen, the clustering accuracy of the proposed algorithm is significantly higher than the other algorithms.

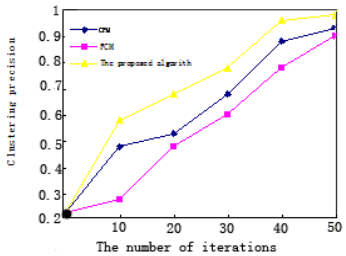

Fig.3: Comparison Of Clustering Accuracy

5. CONCLUSION

In this paper, Societies divided thinking based on Complex network of local modularity is applied, Comprehensive analysis of the state of road traffic, the application node degrees, peak-hour traffic and clustering coefficient, reflects both the static and dynamic characteristics of the transport network node, improves the accuracy of the transport network Hub node identification, more in line with the actual needs of the network traffic control. Based on the urban traffic network of local module Hub node identification algorithm in mitigation and prevention of traffic congestion, directing traffic practice has a significant meaning and practical application of scientific theories.

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