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Temporal network modeling: An empirical analysis

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Abstract: The study of network structure characteristics is the key to understand the function of complex systems. In view of the public transport network, understanding the topological characteristics of the network can provide reference for the planning and design of the transport system. Existing public transportation network modeling focuses on bus and subway networks. As an indispensable part of urban public transport, the public bicycle system lacks attention. In order to explain the evolution mechanism of the public bicycle system, this paper construct the temporal network. In view of the temporal network, the evolution process of its statistical characteristics is revealed.

Keywords: Public bicycles system; temporal network; topological characteristics.

1. Introduction

With the introduction of small-world characteristics of complex networks [1] and scale-free characteristics [2], empirical research on complex networks has become hot, and it is still one of the hot research directions and has been applied to many fields, such as supply chain [3], knowledge graph[4], finance[5], social economy[6], transportation[7]. Urban transportation system is a typical complex system, and the application of complex network theory to study the topological characteristics of public transportation network has become effective Methods. This paper analyzes its topological characteristics and dynamic evolution characteristics by constructing a time-effective network model.

2. Model building

The sample data of the user's loan and return car swiping card is shown in Table 1. Assuming there are four cycling data, there are two trajectories cycling from bicycle rental site A to site B; there is one trajectory cycling from bicycle rental site A to site C; There is a trajectory that rides from bicycle rental site B to site C. The riding time corresponding to each riding trajectory is shown in the fourth column; the time of each riding is shown in the fifth column. In the initial data set, riding The time when the trip occurs is accurate to the hour: minute: second. Due to the needs of research, we only use the time data when the ride occurs. Below, we take these four cycling trajectory data as an example to illustrate the time-dependent network modeling method.

Tab. 1 Sample datas for used vehicles

Trip number	Start station	End station	During/min	Time/h
1	A	B	3	6
2	A	B	5	9
3	A	C	1	6
4	B	C	3	7
...	...	...	...	...

Regarding the bicycle stations as the nodes of the network, there are edges between the nodes when the cycling behavior occurs between the stations. The direction of the edges is from the starting station to the stopping station, and the cycling passenger flow data between the stations is used as the weight of the edge. Time labels are used to mark the time information connected between nodes to construct a time-efficient network. As shown in the example data in Table 1, the four riding trajectories involve a total of three bicycle rental sites at three different time riding information. As shown in Figure 1 , At time t=6, three stations are involved, so the network is composed of three nodes A, B, and C. At this moment, there are two cycling trajectories, one is from bicycle station A to station B, and the other is from bicycle station A to station B. When station A departs and arrives at station C, then there are directed edges from node A to node B and nodes from node A to node C in the network, and the weight of the edges is 1. At t=7, there are two sites involved, Therefore, the network is composed of two nodes B and C. At this moment, there is a cycling trajectory, which starts from bicycle station B and arrives at station C. Then there is a directed edge from node B to node C in the network, and the weight of the edge is 1. . At t=9, there are two sites involved, so the network is composed of two nodes A and B. At this moment, there is a cycling trajectory, which starts from bicycle rental site A and arrives at site B. Then there is node A in the network. A directed edge pointing to node B and the weight of the edge is 1.

3. Temporal network

The time-dependent network model is shown in Figure 1. At t=6, the network contains three nodes A, B, and C, A→B, A→C two directed edges and the weights of the edges are all 1, indicating that at t= At time 6, a passenger departs from station A and arrives at station B and station C respectively. At time t=7, the network contains two nodes B and C, and B→C has a directed edge with a weight of 1, indicating that at time t=7 , A passenger departs from station B and arrives at station C. At t=9, the network contains two nodes A and B, A→B has a directed edge with a weight of 1, indicating that at t=9, there are passengers from station A Departure and arrive at site B. Compared with the static network, the connection between nodes in the aging network is not continuous, and will be shown as sequential and irreversible in time. By analyzing the topological characteristics of the aging network, we can understand the network Change the situation, and then understand the working status of the site.

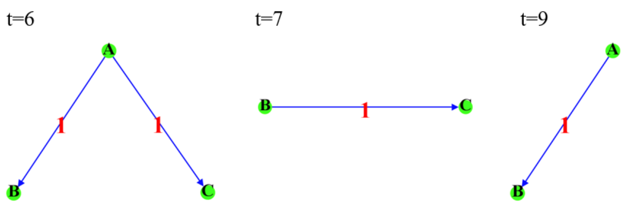


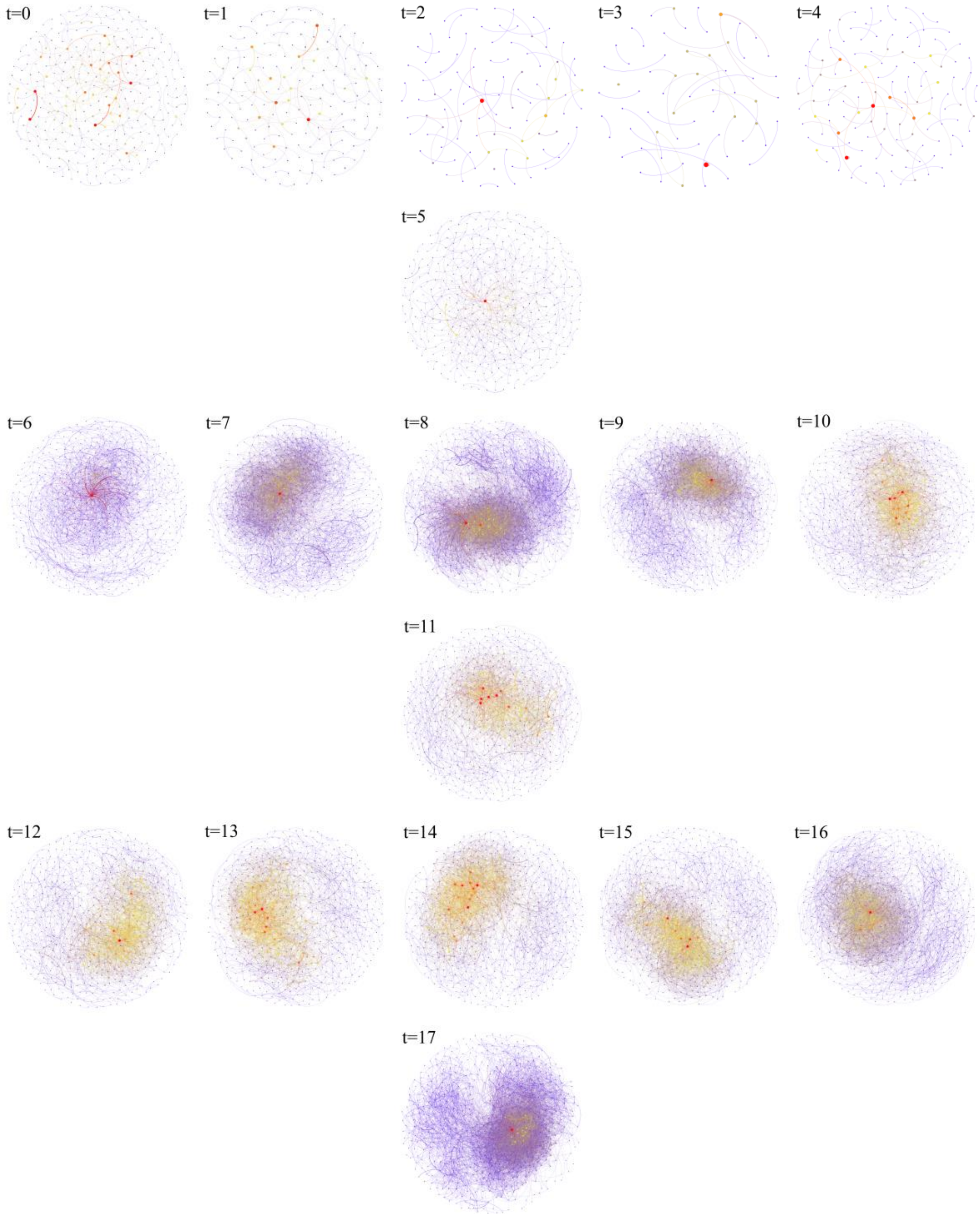
Fig.1 Model of temporal network

4. Empirical analysis

According to the aging network model, we get the aging network diagram of the public bicycle system, as shown in Figure 6. The aging network diagram dynamically describes the changes in the bicycle network at 24 times a day. The nodes in the network correspond to the rental in the bicycle system Stations, the edges in the network represent the cycling trajectory between the two stations. The color and radius of the node reflect the weight of the node. The color of the node in the network is from low to high, which is represented by blue, orange, and red in turn .

By observing the time-dependent network graph, we can find that the network has changed significantly over time. During the time period from 0 to 5, the network is a sparse network, and the network has fewer nodes and edges. The network The connectivity of the network is relatively low. Starting at 6 o'clock, the number of nodes and edges of the network gradually increase, and the growth rate of nodes is much lower than the growth rate of the edges, and reaches a peak at 8 o'clock, after which the edges of the network decrease rapidly, and Maintained at a relatively stable level for a period of time, until 17 o'clock in the afternoon, the network edge appeared the

second peak of the day, and after 1 hour, it decreased to a stable level again.
Based on the analysis of the laws of human activities, it can be seen that 8 o'clock and 17 o'clock respectively correspond to people's working hours and off-get off work hours. We guess that the change in the network structure is due to the change in the network structure due to a large number of cycling during the peak hours of get off work. In order to further understand the changes in network characteristics, the following will analyze the topological characteristic parameters of the network.



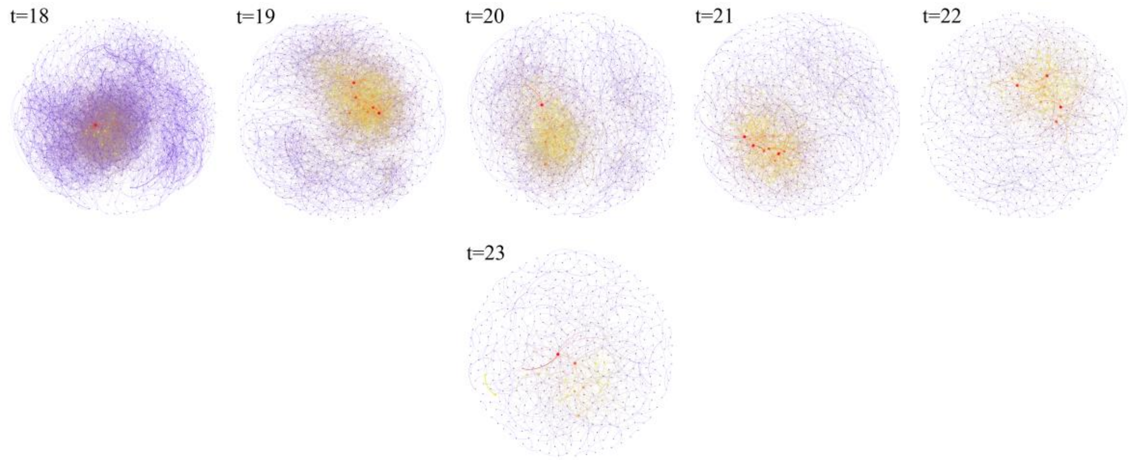


Fig.2 Temporal network of public bicycle system

5. Network topology characteristics

The time-series changes of nodes and connecting edges corresponding to the aging network are shown in Figure3: The abscissa of Figure 3(a) represents time, the unit is hour, and the ordinate is the number of nodes and the number of edges from left to right, respectively. It can be found that: in the early morning of the day, the activity of the site is the smallest. At different times during the day, there are slight fluctuations in the number of sites used. Compared with the nodes, the time series of the edges fluctuates greatly, and exhibits a bimodal distribution Situation. The amount of cycling during the day is much greater than the amount of cycling at night; the peaks occur at 8 am and 17:00 pm, the reason is due to commuting to and from get off work on weekdays.

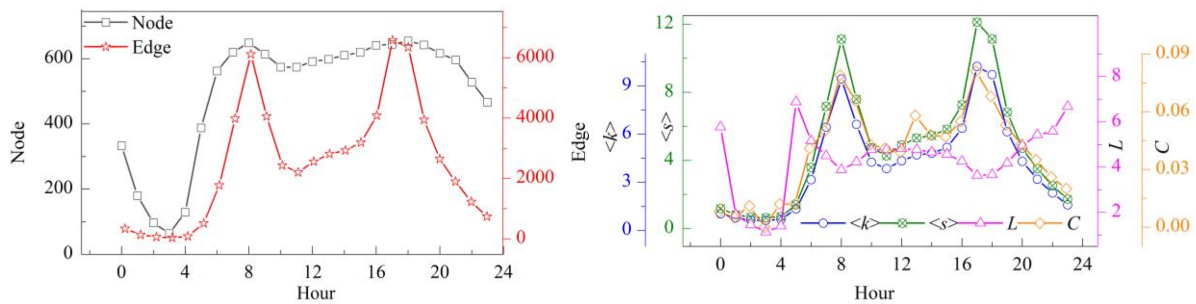


Fig. 3 Temporal network features (*a*) changes of nodes and connection edges (*b*) changes of topology parameters

The topological characteristic parameters of the time-dependent network are highly correlated. As shown in Figure 3(b), the abscissa represents time, and the ordinate from left to right represents the average degree <k>, average strength <s>, and average shortest path length. L and agglomeration coefficient C. Figure 7(b) describes the time series characteristics of the average of the working day statistics. It can be found that the statistics <k>, <s>, C show a highly similar time series trend, and all show The characteristics of the bimodal distribution. The difference is that the shortest path length L has the opposite trend. Combining the timing changes of the time-dependent network edges, it can be found that statistics such as the degree, strength, and agglomeration coefficient in the network are closely related to the density of the network. The denser the network, the larger the aggregation coefficient C of the network, the smaller the average shortest path length L, the better the network accessibility; the denser the network, the greater the average degree <k> and average strength <s> in the network, and vice versa The smaller.

6. Conclusion

This paper combines the passenger flow data between the system sites, uses time tags to mark the information of the connection time between nodes, and builds a time-efficient network. This makes the network more suitable for the situation and fully considers the passenger flow, riding time and time tag pair The impact of the network. The research results verify the effectiveness of the constructed network model, and draw the following conclusions: 1) The passenger flow transportation between stations is unbalanced, and 10% of the routes between the stations bear 90% of the passenger flow transportation tasks. 2) The station's The usage intensity and usage pattern are affected by geographical factors. 3) The topological parameters of the time-dependent network have a strong correlation. The topological parameters of the network are affected by the work day and the get off work day is a bimodal distribution, and the peak values correspond to the working hours and the working hours respectively.

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