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Design and Implementation of a Block Identification Platform for Road Traffic Network Aggregation

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Abstract: The road transport network is an important infrastructure serving the economy, society and the public. Research on the structure of road traffic network and identification of the aggregation function blocks of the network can improve the operational efficiency of the road network and enhance the overall service level of the road network. At present, many scholars have studied the aggregation mode of road network. Based on the existing research results, this paper takes PageRank algorithm and spectral clustering algorithm as the core, adopts Python as the development language, and uses PostgreSQL database for data storage to realise the construction of road traffic network aggregation block identification visualisation platform.

Keywords: Road Traffic Networks; Clustering Algorithms; Pagerank; Block Segmentation; Visualisation Platforms.

1. Introduction

Aiming at how to use the visualisation platform to present the results of road network aggregation block delineation more intuitively and carry out road network aggregation pattern analysis more efficiently, this study carried out the design and implementation of the aggregation block identification and analysis platform for highway traffic network. The platform includes the functions of road network area selection, calculating the number of road network clusters in the area, identifying road network aggregation blocks, and displaying and analysing the aggregation results. In addition to the above points, how to ensure the security of information in the system and the stability of the system operation process is also studied. The research goal is to establish a fully functional and easy-to-operate road traffic network aggregation block identification and analysis platform for the traffic department. This platform will help data analysts in the transport sector to have a clearer understanding of the structure of the road traffic network and also help them to make decisions on the maintenance and construction of the network.

2. Background and Significance of the Study

The road transport network is a critical infrastructure serving the economy, society and the public. It is the backbone of a comprehensive transport system. As the scale of cities continues to expand, the urban population is gradually increasing, making the pressure on urban road traffic ever greater.

The aggregated functional blocks of a road transport network are the dominant structures presenting different characteristics and multiple functions of a complex road transport network. Newman[1] introduced communities, modules and large-scale structures in networks. It was pointed out that communities have intrinsically self-attracting modules, which may correspond to functional units in a network system, as an example of the link between structure and function. Fortunato et al [2] suggested that the detection of communities in networks is one of the hottest topics in modern network science. Communities or clusters are usually groups of vertices, where vertices within a cluster are connected to each other with a higher probability than members of other groups. Yang et al[3,4] applied the concept of community detection to correlation networks of urban traffic states and proposed a new perspective for identifying spatially correlated patterns of traffic states. A suitable clustering algorithm needs to be selected to perform road traffic network aggregation pattern analysis. There are many algorithms for identifying network aggregation features, such as vertex clustering algorithms [5-7], density-based algorithms [8-10], random wandering method [11-13], and spectral clustering algorithms [14]. Zhu xia et al [15] used k-means clustering algorithm for road traffic network analysis in their study. Road traffic network data are typically high-dimensional data, and the ideal clustering clusters of road traffic network data have various shapes. The advantage of spectral clustering algorithm is that it is suitable for analyzing high-dimensional data, and it has the characteristics of being able to cluster on any shape of sample space and converge to the global optimal solution. Therefore, spectral clustering is more suitable for road traffic network aggregation pattern analysis.

Based on complex network theory, this paper provides an in-depth analysis and research on the aggregation mode of road traffic network. The PageRank algorithm and spectral clustering are applied to construct a platform for identifying and analysing the aggregation blocks of road traffic network, which facilitates the analysis of road network aggregation for the traffic department.

3. Introduction to the system core algorithm

3.1. Improved PageRank Algorithm to Determine Criticality Node Rankings

The PageRank algorithm itself is used by Google Chrome as the only measure of how good a website is. Google defines the level of a website on a scale of 0 to 10, where 10 means a perfect score. The higher the PageRank the more important (and popular) the web page is. The advantage of the PageRank algorithm is that it takes into account feedback on the importance of the links to the other pages and is suitable for analysing road traffic networks. importance feedback, which makes it suitable for analysing road traffic networks.

The higher the connectivity of a road node, the more important the road node is in the road traffic network, without considering any weighting. However, the disadvantage of PageRank algorithm is that it does not consider the influence of the importance of the nodes themselves. In this study, the PageRank algorithm is improved by considering the influence of the importance of the road node itself and adding the location, road class, distance, and dynamic traffic congestion degree weight influence factors in the real traffic network. The critical node rank ordering situation of road traffic network obtained by using the improved PageRank algorithm is more in line with the actual situation of road traffic network.

3.2. Determine the Centre of Clustering and The Number of Clusters

Alex Rodriguez and Alessandro Laio point out that clustering centres have both of the following properties:

(1) Cluster centres are important nodes surrounded by low-impact neighbours;

(2) The initial clustering centres are evenly distributed in the physical network and the 'distance' between the centres is relatively large.

In this study, a two-dimensional decision diagram is used to select the clustering centres and the number of clusters.

3.3. Improved Spectral Clustering Algorithm for Functional Block Delineation of Road Traffic Networks

At present, the method used in the study of road traffic network functional block division is mostly k-means clustering algorithm. But k-means clustering algorithm is a prototype-based clustering. Its premise assumption is that the clusters are spherical. So when using k-means clustering, the original clusters are spliced to make them appear closer to a spherical shape. Therefore, k-means is better for grouping spherical clustered clusters and not good for classifying non-spherical clusters, clusters of different sizes and densities. And spectral clustering algorithm is based on spectral graph theory. It has the characteristics of being able to cluster on the sample space of arbitrary shape and converge to the global optimal solution. That is, it is more adaptable to data distribution. In addition, the spectral clustering algorithm uses the dimensionality reduction technique. It is more suitable for dealing with high dimensional data such as road traffic network. Taking the above considerations into account, this paper uses the spectral clustering algorithm to divide the functional blocks of road traffic network. The basic idea of spectral clustering is to decompose the features of the Laplace matrix of the sample data. Using the Laplace matrix feature vector data characteristics and based on data mining technology to cluster analysis, and then form a specific clustering scheme. Considering the actual situation of road traffic network, this paper improves the spectral clustering algorithm. On the basis of the similarity matrix, the location, distance, road class and traffic congestion degree weighting matrix are added to get a new weighting matrix in line with the actual road network situation. Then the clustering is carried out to get the results of road traffic road network functional block division.

4. System Function Module Design

4.1. Regional Selection

The function realised by the area selection module is to select the road network area to be divided into blocks. The main interface displays a map of the People's Republic of China. The map can be zoomed in and out by scrolling the mouse. In the lower right corner of the main interface, there are two buttons, namely 'Box Selection Area' and 'Confirm Box Selection'. The user enters the area to be boxed by clicking the 'Boxed Area' button. For example, select 'Guangyang District, Langfang City, Hebei Province', and then click 'OK box', the system will automatically locate the area. At the same time, the background will be synchronised to store the information of the boxed area, in order to prepare for the next step of the 'number of computer clusters' for its use.

4.2. Calculate the Number of Clusters

The Calculate Number of Clusters module calculates the number of clusters for the road traffic network in the selected area. The user clicks the 'Calculate Clusters' button to calculate the number of clusters of the road traffic network in the selected area. When the user clicks the 'Calculate Clusters' button, the backend receives the calculation command and executes the improved PageRank algorithm to calculate the key nodes, the number of clusters and the cluster centre. At the same time, the number of clusters and cluster centres are stored internally for use in the next step of aggregation block identification.

4.3. Aggregate Block Recognition

The function of the aggregation block identification module is to obtain the results of aggregation block identification. The user clicks on the 'Function Block Identification' button to classify the clustered blocks of the road traffic network in the target area. When the user clicks the 'Function Block Identification' button, the background receives the calculation instruction and executes the improved spectral clustering algorithm to get the road traffic network aggregation block classification results, which are displayed on the interface.

4.4. Aggregation Results Presentation and Analysis

The function of the Aggregation Results Presentation and Analysis module is to calculate the shortest distance paths (critical paths) between aggregated blocks of the road traffic network. The user clicks on the 'Show & Analyse' button to calculate the critical path. When the user clicks on the 'Show and Analyse' button, the background receives the command to execute the Dijkstra's algorithm and the greedy algorithm to calculate the shortest distance path connecting the cluster centres. At the same time, the shortest distance paths connecting the centres are displayed on the interface with blue bold lines, which is convenient for the relevant personnel of the traffic department to analyse the critical paths. In addition, when the user clicks on a section of the path, the interface will display the longitude and latitude of the nodes at both ends of the path, so that the relevant personnel of the traffic department can quickly locate the actual position of the path, which in turn facilitates their maintenance and repair of the path.

5. System Design Results

5.1. System Main Interface

The main interface of the road traffic network aggregation block identification and analysis platform is shown in Figure 1. The whole main interface of the platform is simple and easy to operate.

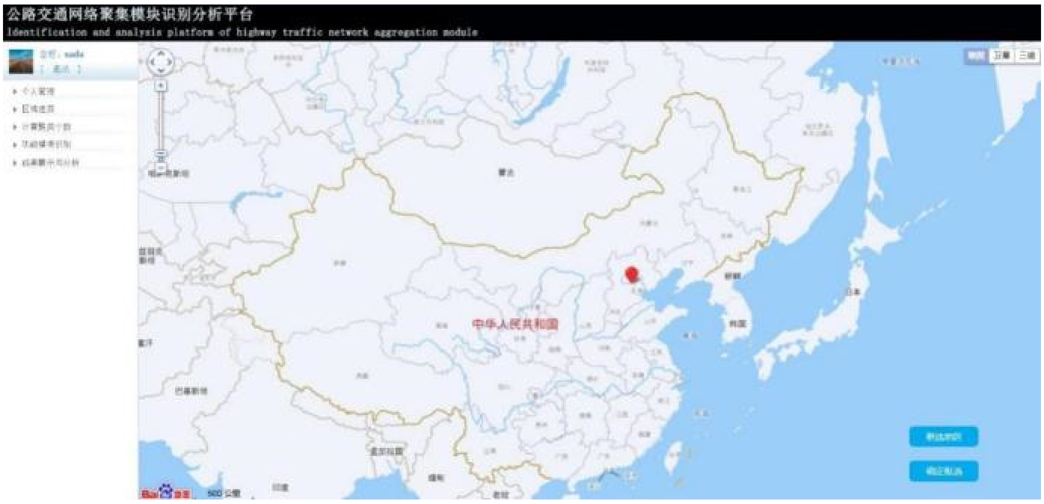

Figure 1. System main interface

5.2. Area Selection Function Interface

The function realised in the area selection section is that the user can select the road network area by inputting the names of provinces, cities and counties. The system will delineate the road network area according to the user's input. After the user clicks the OK button, the background will store the parameter values of the selected area into the database and present the selected area on the page. The effect is shown in Figure 2.

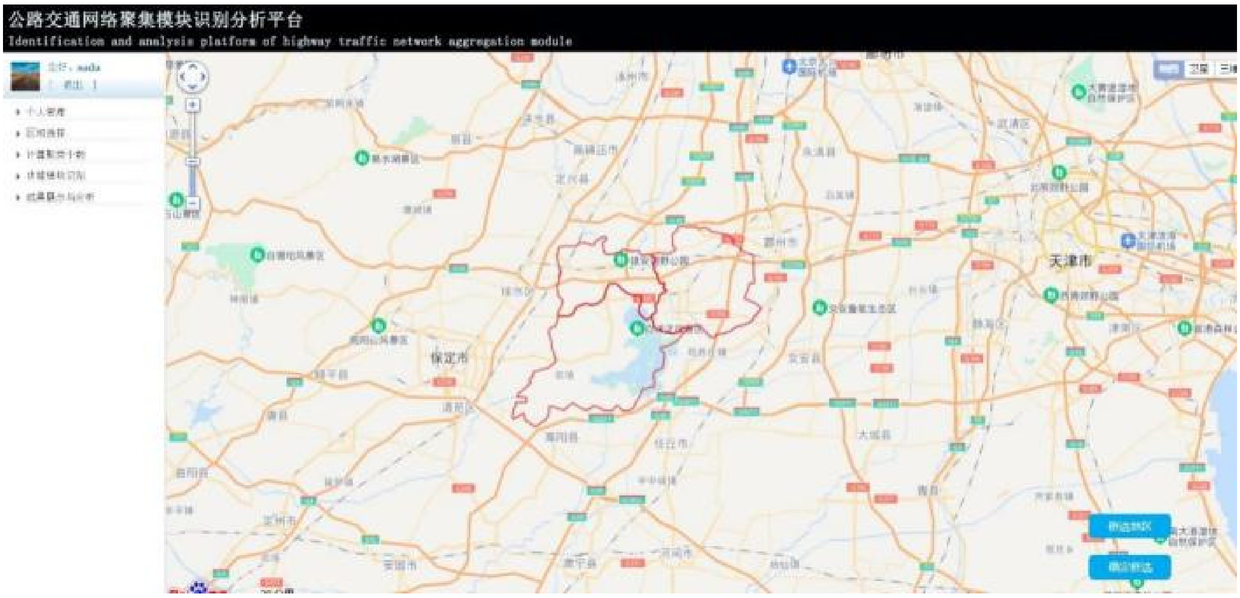

Figure 2. Region Selection Function Demonstration

5.3. Calculate Number of Clusters Function Interface

The Calculate Number of Clusters function implements the calculation of the number of clusters for the selected road network area. The function is mainly embedded with the PageRank algorithm for criticality node sorting based on the improved road network weights. Combining the criticality node sorting algorithm and the shortest path distance draws a two-dimensional decision graph, determines the clustering centre, and displays the decision result graph on the interface. As shown in Figure 3, the number of nodes in the red box in the decision graph is the number of clustering centres.

5.4. Area Selection Function Interface

The clustered block identification function implements the identification of clustered blocks of the road network in the selected area. The function is mainly embedded with a spectral clustering algorithm that is improved based on the actual characteristics of the road network. The system combines the number of clusters and the spectral clustering algorithm to identify the aggregated blocks of the road traffic network in the selected area, and displays the clustering results on the interface. The left side of the interface is the road network map to be identified by aggregation blocks, and the right side of the interface is the road network division map after the aggregation block identification. The effect is shown in Figure 4.

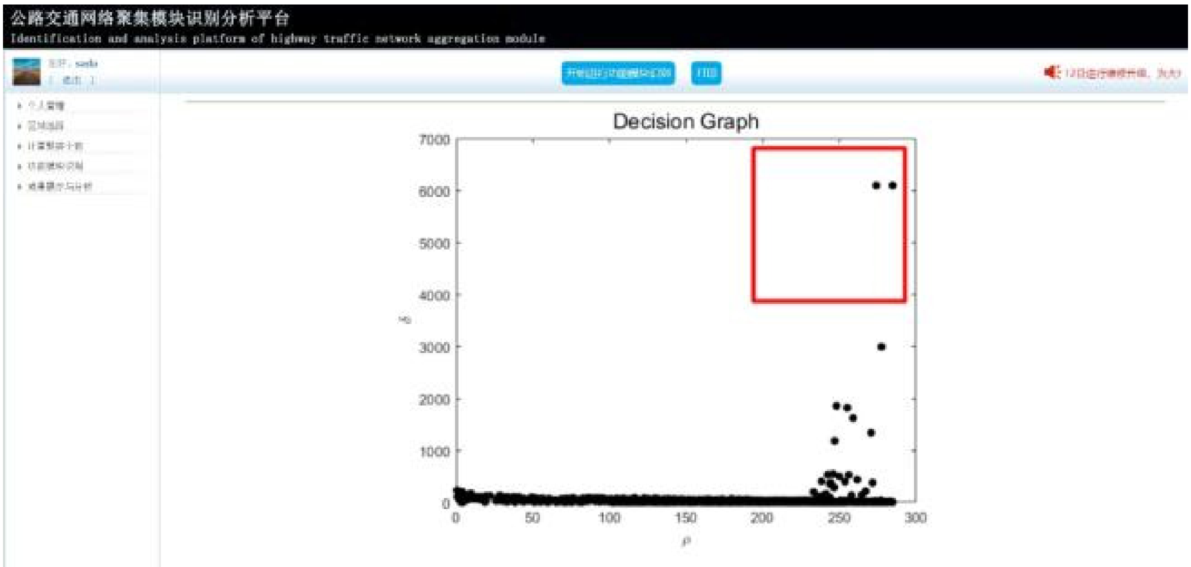

Figure 3. Demonstration of the functionality of the clustering centre of the computational road network

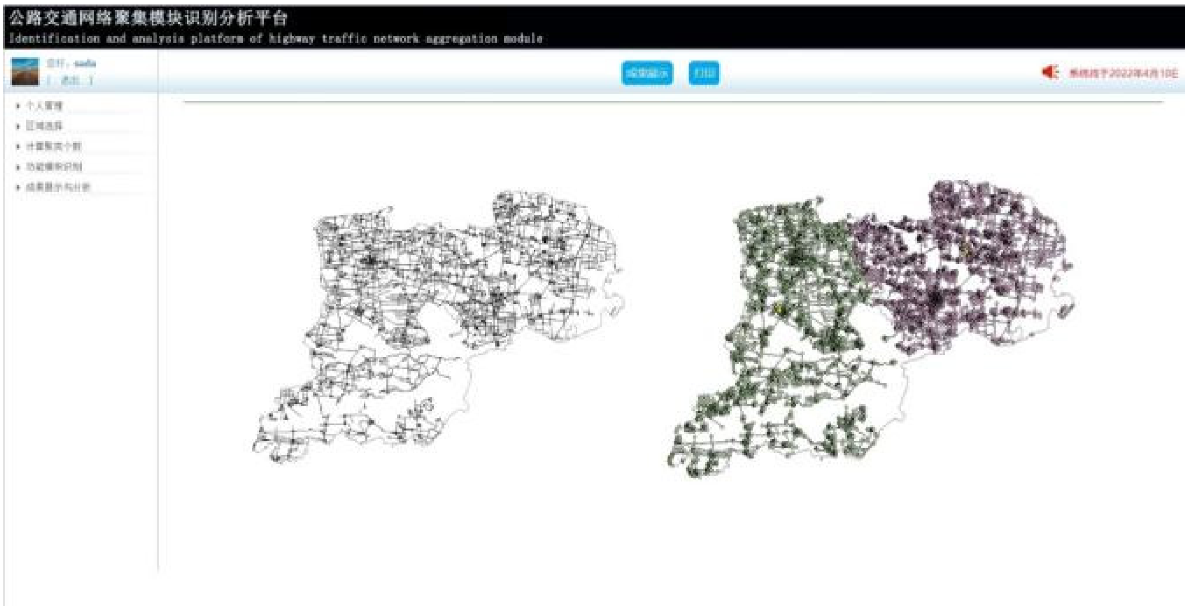

Figure 4. Demonstration of Aggregate Block Recognition

5.5. Results Presentation and Analysis Functions

The results presentation and analysis function enable the presentation of the final results of the road traffic network aggregation block identification. The system is embedded with Dijkstra's algorithm and greedy algorithm to identify the shortest distance paths (critical paths) connecting the centroids, and displays the identified critical path results on the interface. The effect is shown in Figure 5. At the same time, selecting the path node on the interface and then right-clicking the mouse, the corresponding node information of the critical path can be viewed. The effect is shown in Figure 6.

6. Concluding Remarks

(1) This design uses Visual Studio Code, the more mainstream development tool in software project development today, to develop the project. PostgreSQL is used to achieve the creation of the database. The system completes the operation process from the selection of road traffic network areas to the division of road traffic network aggregation blocks and gives the critical paths between the blocks. The system is embedded with improved PageRank algorithm and spectral clustering algorithm, which makes the results of road traffic network aggregation block delineation closer to the actual situation, and then can provide decision-making references for road maintenance and conservation of the transport sector.

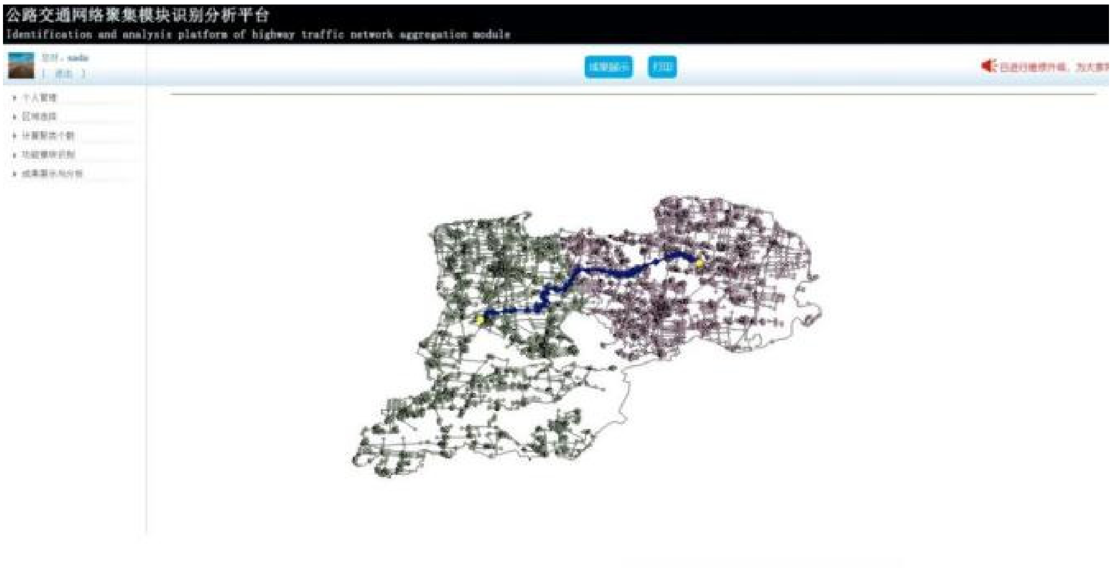

Figure 5. Critical Path Analysis Results Presentation

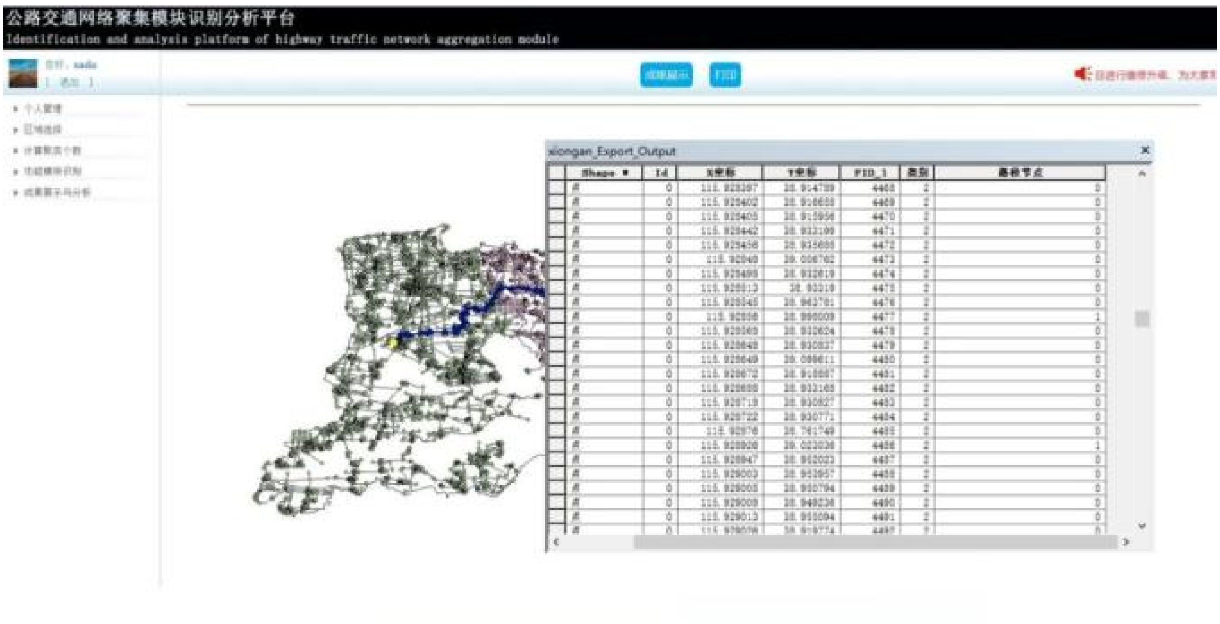

Figure 6. View a demonstration of the critical path node functionality

(2) The system achieves the expected goal through debugging and running, and is stable and expandable. We will consider adding more road network service functions to make the system more mature and provide better services for the traffic department.

Acknowledgments

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