Exploring the Rationalization of Bus Stop Layout: A Case Study of Changning District, Shanghai

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Abstract. With the rapid development of urbanization in China, many large cities have carried out large-scale traffic development and construction. However, its rapid development will inevitably lead to the imbalance of urban spatial distribution, structural disorder, traffic chaos and other situations. Therefore, this paper takes Changning District of Shanghai as the research object, and adopts the grouping method based on Tyson polygon and hotspot analysis method to study the urban space of Changning District of Shanghai from the perspective of urban space structure and bus stop layout.

Keywords: Bus Stop Layout · Rationalization analysis · Tyson Polygon · Shanghai

1 Introduction

Urbanization is an irreversible process of human society, and both developed and developing countries need to go through this stage. And many experts and scholars have studied the urban spatial distribution and hot spots [1–3]. At the same time, various analysis methods are constantly applied to urban spatial analysis [4–8]. Many new algorithms have been introduced into spatial analysis, which has a data-driven quantification of the space, and has a great complement and innovation significance to the traditional algorithms [9–15].

In this paper, Changning District of Shanghai is taken as the target area, the grouping method based on Tyson polygon and hotspot analysis method are used to analyze the urban space. Based on the bus stops in Changning District, Shanghai was clustered as a way to partition Changning District. The Baidu map heat map was used for comparison to explore the rationality of bus stop establishment in Changning District. Exploring the applicability of a Tyson polygon-based grouping approach with hotspot analysis methods in utility distribution studies.

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2 Data and Study Area

Point data for each bus stop in Shanghai (included in the included routes) was used. Changning District is located in the western part of the central city of Shanghai, bordering other districts. The industrial structure, dominated by tertiary industries, determines extremely high population mobility within and between the regions. Changning District is selected as the study area and is of reference value for the evaluation of urban construction in Shanghai.

3 Methodology

3.1 Tyson Polygon

This method applies to point data and each Tyson polygon contains only one point input element. Tyson polygon characteristics: any position in a Tyson polygon is closer to its associated point than it is to any other point input element. In this way, Tyson polygons can be used to delineate regions, i.e. Tyson regions.

ArcGIS construction idea: Construct a Delaunay Irregular Triangulated Network (TIN) based on the input points. The vertical bisectors of the sides of a triangle form sides of Tyson polygon. The intersection of the bisectors determines the location of Tyson polygon fold. The outer boundary of the output Tyson polygon element class is the range of the point input element plus 10%.

3.2 Grouping Method

Given the number of groups to be created, based on the selected analysis field parameters, with additional spatial or spatial-temporal constraints, a connectivity diagram (minimum spanning tree) will be used to find natural groupings that make all elements in each group as similar as possible but as different as possible from one group to another. The grouping analysis requires a unique integer attribute, similar to a key in a database.

The spatial or spatial-time-space constraints used in this attempt are:

(1) CONTIGUITY_EDGES_ONLY: Elements belong to the same group only if they share an edge with another member of the group (applies to face elements that are contiguous or have adjacent neighbours).
(2) CONTIGUITY_EDGES_CORNERS: Elements belong to the same group when they share an edge or a fold with another member of the group (for face elements that are contiguous or have adjacent neighbours).
(3) DELAUNAY_TRIANGULATION: An element is included in a group when at least one other group member is a natural neighbour (Delaunay triangle).
(4) K_NEAREST_NEIGHBORS: An element is included in a group when it has at least one other member, a "K nearest neighbour" (suitable for a point or face elements, not for datasets with overlapping elements).
(5) NO_SPATIAL_CONSTRAINT: The grouping analysis tool will use the K-means algorithm. Grouping analysis tools use unsupervised machine learning methods to determine the natural groupings in the data. (Analyses that do not require the imposition of spatial or spatial-temporal constraints may choose to include some analysis fields for spatial variables to capture certain spatial characteristics.)

3.3 Hotspot Analysis

The hotspot analysis tool calculates the Getis-Ord Gi* statistic (called Gi*) for each element in the data-set. The resulting z-score and p-value are used to know where in space clustering of high or low-value elements occurs.

The ArcGIS clustering idea is to look at each element in the neighbouring element environment. High-value elements are often easy to notice, but may not be statistically significant hotspots. To be a statistically significant hotspot, elements should have high values and be surrounded by other elements that also have high values. The local sum of an element and its neighbouring elements will be compared with the sum of all elements; a statistically significant z score will be generated when the local sum is so different from the expected local sum that it cannot be a randomly generated result. If the FDR correction is applied, statistical significance is adjusted for multiple testing and spatial dependence. Whether the input element class contains at least 30 elements, if less than 30 elements, the results are not reliable.

Selecting the appropriate spatial relationship: The default fixed distance range method was used for this experiment for the following reasons: the face data used was constructed from point data via Tyson polygons, so it can be seen that the faces at the boundary of the study area are larger and the faces at the centre of the study area are smaller, and this method was chosen to ensure that the analysis was proportionally consistent.

4 Process and Results

4.1 Data Process

In the Shanghai bus station.shp file, select the data with the area attribute "Changning District" from the attribute table, and delete the other data. Count the number of routes contained in each station in the newly generated Changning District bus station file, and enter the newly generated int-type attribute: number of routes. The Tyson polygon tool in ArcGIS was used to construct a Tyson polygon for each bus station in the Changning District so that the area could be divided based on the service area of the bus station. The Tyson polygons were pre-processed and analyzed by using the ArcGIS cluster distribution mapping tool, grouping analysis, hotspot analysis and optimized hotspot analysis to obtain the partition map.

The results of the clustering methods were compared, and the current situation of Changning District was combined to evaluate the rationality of the establishment of bus stops in Changning District and to summaries the differences and applicability of different clustering tools. And the specific steps of data processing are shown in Fig. 1.

4.2 Results

Tyson Polygon result is shown in Fig. 2. And the results of the clustering methods are shown in Fig. 3(a)-(d). Different color means different cluster.

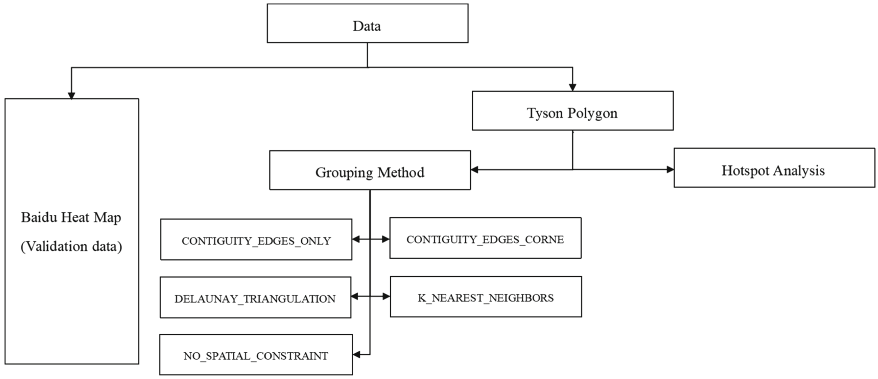


Fig. 1. Workflow chart

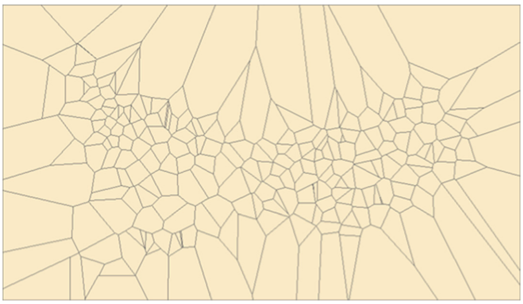
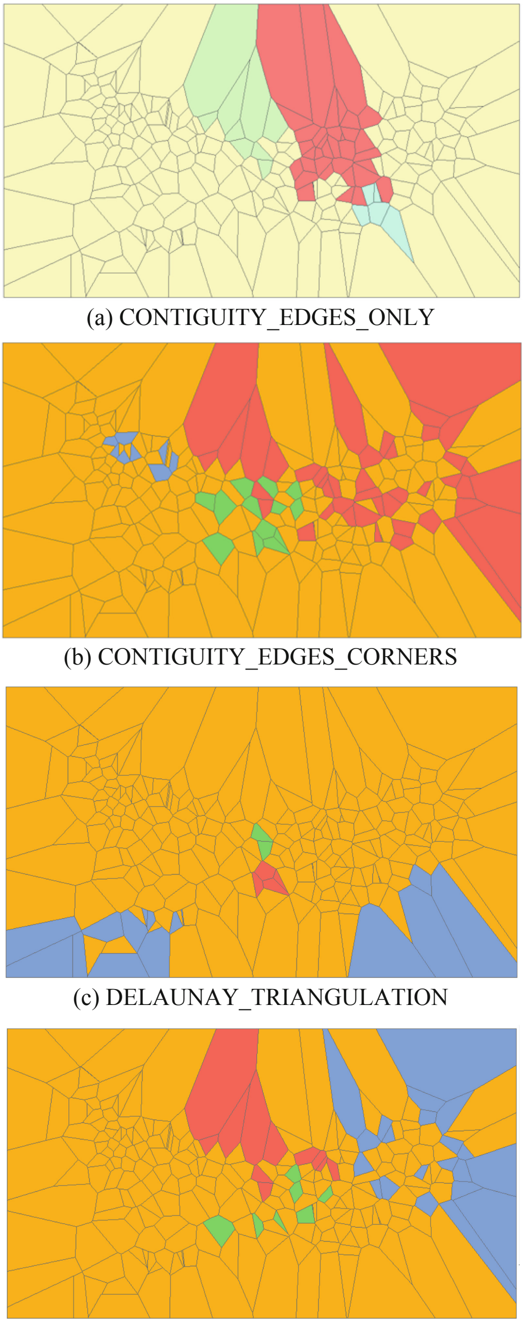


Fig. 2. Tyson Polygon result

5 Analysis and Discussion

Although in terms of presentation, the grouping analysis appears to be closer to the original data, the inclusion of spatial constraints and the fact that the variation in values of the elements analyzed in this study is not very large. The hotspot analysis results are shown in Fig. 4. The variability between groups and the similarity of data within groups is reduced when grouping and the grouping results are fragmented. And highly susceptible to different spatial constraints, making the grouping results unstable. The hotspot analysis tool is statistically significant in that to be a statistically significant hotspot, elements should have high values and be surrounded by other elements that also have high values, which can better reflect the aggregation characteristics between regions, making it easier to compare the placement of bus stops in each region with the real pedestrian flow.

The results of the hotspot analysis show that the hotspots are concentrated in the central northern part of Changning District, similar to the heat map (Fig. 5). To a certain extent, it reflects that the existing bus stops are consistent with the distribution of



(a) CONTIGUITY_EDGES_ONLY

(b) CONTIGUITY_EDGES_CORNERS

(c) DELAUNAY_TRIANGULATION

(d) K_NEAREST_NEIGHBORS

Fig. 3. Grouping results

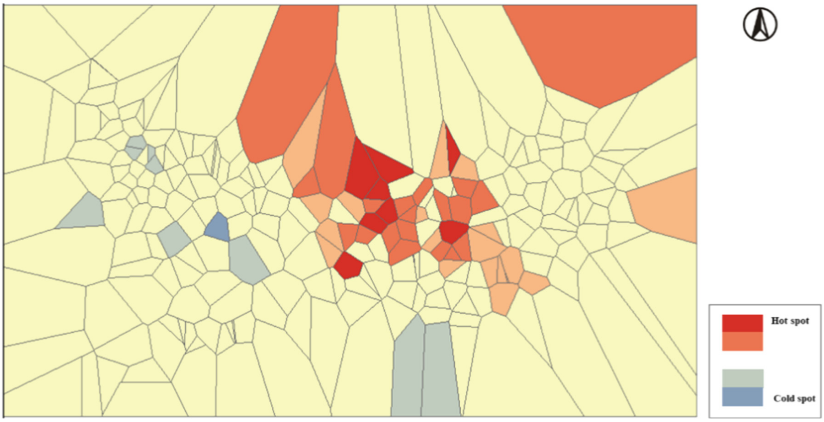


Fig. 4. Hotspot analysis results

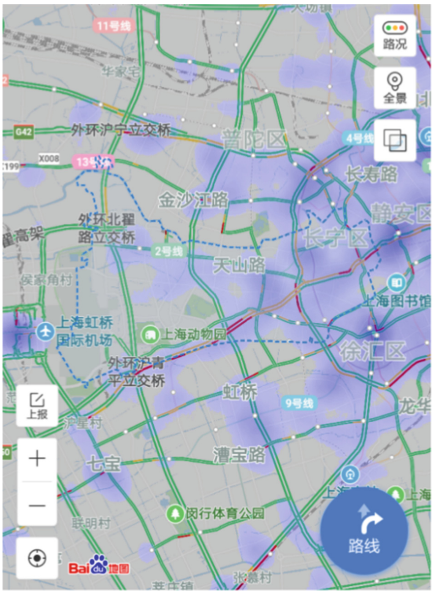


Fig. 5. Baidu Heat map

pedestrian flows and can better meet the needs of pedestrian flows and divert them. The following limitations exist in this study.

(1) The northern edge of Changning District is classified as a statistically insignificant area in the hotspot analysis, and the central edge is classified as a cold spot, which is different from the heat map. This may be related to its location as an edge and the data around it being removed, and it is recommended that the peripheral data be added for another clustering analysis.

(2) In addition, the judgement of this study is rather rough. If conditions and data are available, it is advisable to add data from the road network, metro lines and important public places for comprehensive analysis and comparison, to obtain more accurate evaluation results.

6 Conclusions

Compared to group analysis, hotspot analysis is more applicable to the study of the rationality of bus stop layout. A comparison of the results of the hotspot analysis with the footfall heat map shows that the existing bus stop layouts in Changning District, Shanghai are more reasonable.

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