Spatial Differences of Commercial Vitality in Main Urban Area of Kunming City, China

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Abstract: The data used in this study includes 100,305 Point of Interest (POI) collected in 2022. The spatial pattern of commercial vitality in the main urban area of Kunming City and its differentiation are analyzed by average nearest neighbor distance analysis and kernel density estimation. The results show that: (1) The overall spatial distribution is unbalanced, indicating that there may be discrepancies in the development of commercial activities throughout the city. (2) The spatial distribution of commercial vitality in the main urban area of Kunming City is not balanced, and the spatial distribution of commercial vitality in the core area of the urban area differs greatly from that outside the first ring road. (3) The hotspots of commercial vitality are mainly located in the first ring of the core area, as well as the southeast area of the new urban district and the second and third rings.

Keywords: POI data, Commercial vitality, Kernel density estimation, Average nearest neighbor distance analysis, Kunming

1. Introduction

The commercial activities within a city, along with the physical spaces they occupy, generate a certain level of vitality, thereby reflecting the overall vitality of the urban area [1]. As a result, understanding the spatial arrangement of urban commerce has become a significant focus in this field. The dynamic interconnection between people, their activities, and their living environments, as well as the diverse nature of urban life, contribute to the vibrancy of cities. The vitality of a commercial entity can provide insights into the surrounding commercial landscape, which, in turn, can inform regional commercial development trends and facilitate more informed investment decisions [2]. Jane Jacobs, a prominent urban theorist, utilized indicators such as pedestrian flow, street length, and land type to assess the vitality of commercial spaces [1]. While traditional approaches to measuring commercial vitality often rely on qualitative analysis, the advent of big data technology has enabled the quantification of commercial vitality using urban hotspot data, specifically Point of Interest (POI) data. This data is characterized by its high precision, real-time availability, and easy accessibility. Consequently, this paper adopts a POI big data approach to identify urban spaces and various facilities, saving considerable time when compared to traditional field research methods. Additionally, using POI data provides effective insights for urban space research, allowing for a comprehensive analysis of the spatial structure of commercial vitality within a city [3].

Based on the above analysis, this paper takes the data of 100,035 POIs in the main urban area of Kunming City in 2022 as the basis and selects five POI data categories: leisure and entertainment, shopping and retailing, catering services, financial services, and lodging services, as the indicators of commercial vitality [4]. The research utilizes various methods such as average closest neighbor, density analysis, and kernel analysis. By employing these methods, the study intends to explore the spatial characteristics and variations of commercial vitality in Kunming City. This analysis can contribute to the rational selection and layout of urban commercial sites, as well as the enhancement of overall urban commerce vitality. It is of significance to the study of commerce in a spatial context.

2. Research Methodology and Data Sources

2.1. Study Area and Data Sources

This paper takes the main urban area of Kunming City as the research area, which mainly includes

the core area, the second ring area, the third ring area and the new urban district, with a total area of 500 km². This paper chooses leisure and entertainment, shopping service category, catering service category, financial service category and accommodation service category data for measuring and analyzing commercial vitality, and obtains 100,035 point data according to the above classification. The attributes and spatial data of commercial points are obtained from the Golder Map POI (December 2022 data).
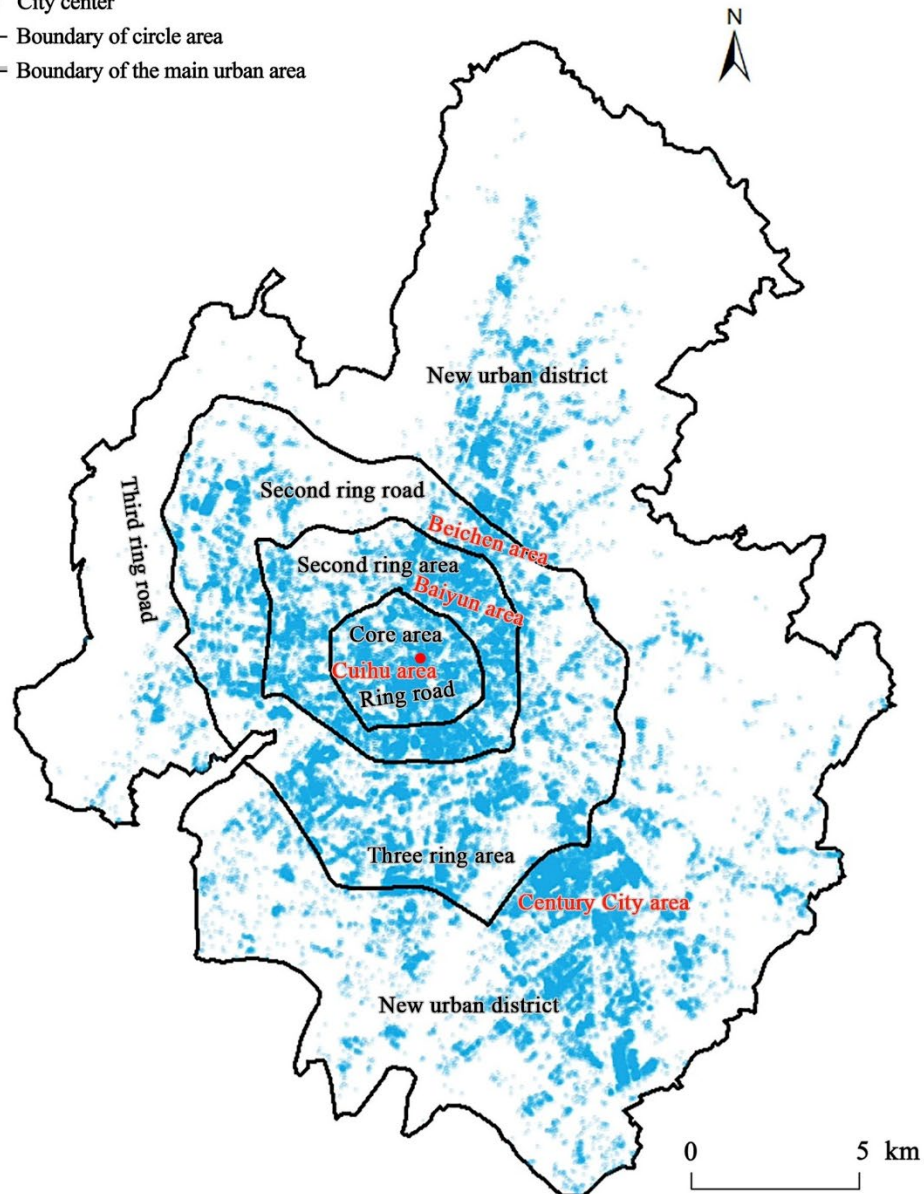

Figure 1: The main urban area of Kunming City and the distribution of commercial points.

2.2. Research Methodology

2.2.1. Average Nearest Neighbor Distance Analysis

The average nearest distance between commercial vitality data points can determine the average distance between them. Based on the ratio R, which is calculated as the measured average nearest distance value (d_i) divided by the expected value (d_e), we can judge the spatial distribution characteristics of these points, which can belong to one of three categories: uniform, clustered, and random distributions. The range of R is between 0 and 2.149, and the ratio R can be expressed as follows:

$$R = \frac{d_i}{d_e} \tag{1}$$

Where d_e can be expressed as:

$$d_e = \frac{1}{2}\sqrt{N/A} \tag{2}$$

Where N is the number of commercial points and A is the main urban area of Kunming City. When $R<1$, it indicates that the commercial vitality data points are clustered; when $R>1$, the data points are discretely distributed; and when $R=1$, the distribution of commercial vitality data points is random. Its standard deviation Z is expressed as [5]:

$$Z = \frac{(d_i - d_e)\sqrt{N^2/A}}{0.26136} \tag{3}$$

2.2.2. Kernel Density Analysis

To analyze the spatial patterns of commercial vitality in the main urban area of Kunming City, this paper uses the kernel density estimation method, which involves calculating the density of each elemental point and superimposing them to obtain the distribution hotspots of outlets. The estimation formula of kernel density is applied in this research. The estimation formula of kernel density is [6]:

$$\lambda_{(s)} = \sum_{l=1}^{n} \frac{1}{\pi r^2} \varphi\left(\frac{d_{ls}}{r}\right) \tag{4}$$

where $\lambda_{(s)}$ is the kernel density estimate for the point s, r is the search radius of the kernel density function, n is the number of samples, and φ is the weight of the distance d_{ls} between the commercial point s and l.

2.2.3. Global Moran's index

Global Autocorrelation Index (GMI) and Local Autocorrelation Index (LMI) Spatial autocorrelation reflect the degree of correlation between a geographic phenomenon or a value of an attribute on one regional unit and the same phenomenon or value of an attribute on a neighboring regional unit. The GMI is expressed as[7] :

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(x_i - \bar{x})(x_j - \bar{x})}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \tag{5}$$

$$S^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n} \tag{6}$$

Where: I is the global Moran index; x_i is the density of commercial data points in the ith block (or neighborhood, community, the same below), and W_{ij} is the spatial weight matrix of each block if the distance between blocks is within the specified threshold distance, the weight is 1, indicating that it has a greater impact on the block, and if it is greater than the threshold distance set the weight is 0, indicating that there is no impact on the calculation of the block.

2.2.4. Local Spatial Autocorrelation Analysis

Based on global autocorrelation of commercial data point density in the main urban area of Kunming City, local autocorrelation characteristics of the space may also occur, therefore, local autocorrelation is measured by using the local autocorrelation index (LMI), which can be expressed as[8] :

$$I = \sum w_{ij}{}' Z_i Z_j\, i \tag{7}$$

where I is the local correlation index, W_{ij} is the row normalization of W_{ij} , and Z_i and Z_j are the normalized values of density. At 5% significance level, if both I_i and Z_i are positive, it means that the density of business locations in both the ith block and its nearby community is high, i.e., high high agglomeration (HH); similarly, if I_i is negative and Z_i is positive, it is high low agglomeration (HL); if I_i is positive and Z_i is negative, it is low low agglomeration (LL); and if both I_i and Z_i are negative, it is low high agglomeration (LH).

3. Results

3.1. Nearest Neighbor Analysis Results of Commercial Vitality in the Main Urban Area of Kunming City

Based on the analysis provided, it can be inferred that the main urban area of Kunming City exhibits

a strong spatial agglomeration characteristic in terms of commercial points. The average nearest neighbor distance analysis indicates an average distance of 17.47 m, which is lower than the expected average distance of 41.69 m, suggesting a clustering of commercial points. In addition, Table1 also shows five categories of commercial points are strongly spatially clustered, in which catering service commercial points have the strongest agglomeration, and the shopping and retailing commercial points have relatively poor agglomeration, which indicates that they have lower commercial vitality compared to the catering service commercial points.

Table 1: Results of Nearest Neighbor Distance Analysis.

Form	R-value	P-value	Z-score	Characteristic
Leisure and entertainment	0.429	0.000	-50.815	Strongly aggregation
Shopping and retailing	0.437	0.000	-253.048	Strongly aggregation
Foodservice category	0.381	0.000	-217.782	Strongly aggregation
Financial services	0.413	0.000	-55.437	Strongly aggregation
Accommodation services	0.410	0.000	-91.011	Strongly aggregation
Total commercial points	0.419	0.000	-351.446	Strongly aggregation

3.2. Kernel Density Analysis Results of Commercial Vitality in the Main Urban Area of Kunming City

The kernel density function was utilized to analyze the distribution of commercial vitality in the main urban area of Kunming City. Subsequently, the obtained kernel density three-dimensional display map (Fig. 2) was visualized in ArcScene. The results reveal a high concentration of commercial vitality in the core area of the first ring (Cuihu area) within the main urban area of Kunming City. Moreover, two low-density hotspots are observed outside the first ring in the northeast and southwest directions (Beichen and Baiyun areas). Additionally, a higher-density hotspot emerges in the southeast direction of the new urban district (Century City area). Meanwhile, scattered low-density hotspots are present within the third ring road. Overall, the commercial vitality in the main urban area of Kunming City demonstrates significant concentration within the local core area (First ring road), as well as dispersed spatial concentration outside the first ring road. The core area of the first ring dominates as the highly active region for commercial vitality, while areas with higher commercial vitality are primarily distributed beyond the first ring. Conversely, areas with low vitality values are primarily concentrated in the new urban district, indicating an imbalanced spatial distribution of commercial vitality.
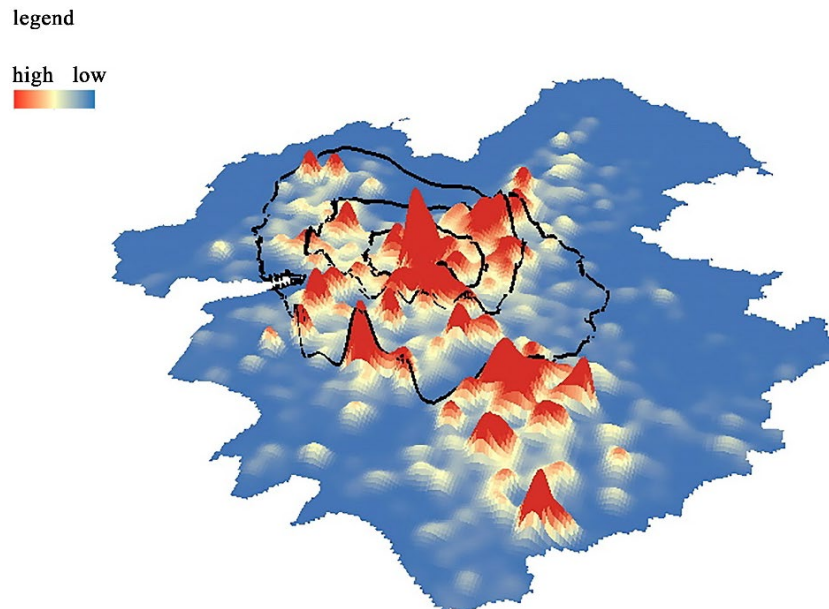

Figure 2: Three-dimensional presentation of commercial vitality kernel density.

3.3. Three-dimensional Display of Grid

Firstly, a 500×500m grid was used as the basic unit of analysis, and a three-dimensional display map

was generated (Fig. 3). The distribution of commercial vitality POI density was found to be uneven throughout the city. The highest density values were concentrated in the city center, but there were also relative differences within this high-value area. Some extremely high-density grids exhibited a sub-density surround pattern, indicating a concentration of commercial vitality POIs in those areas.
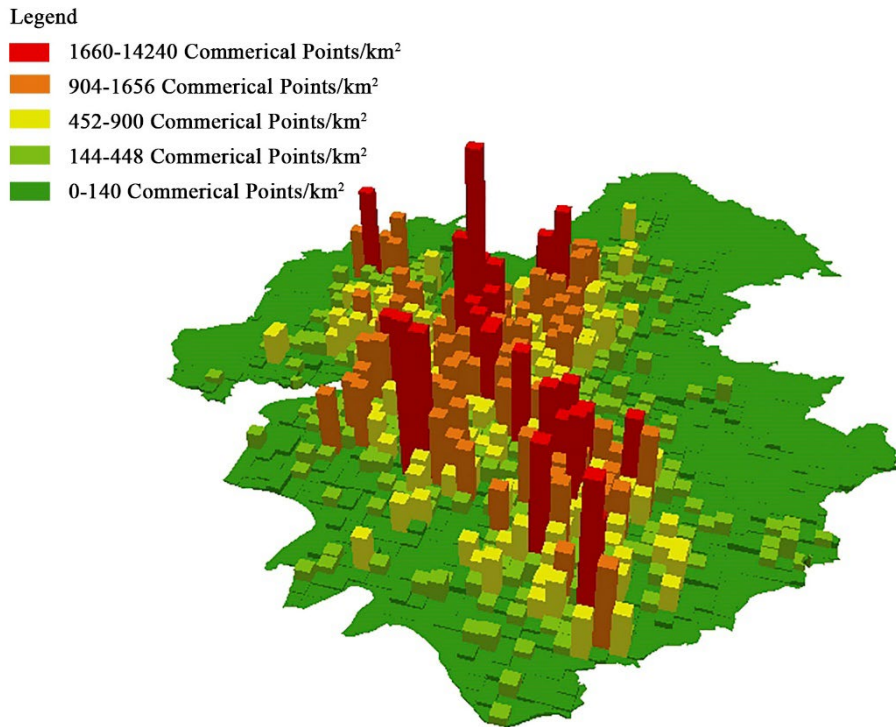

Figure 3: Three-dimensional presentation of the density of commercial points on the grid.

3.4. Spatial Autocorrelation Analysis

According to Moran's I index to judge the spatial correlation and agglomeration characteristics of the density of commercial vitality spots in the main urban area of Kunming city. The FD method was adopted as the basis for judging the spatial weight matrix, and the resulting Moran's I index, Z score, and P value are shown in Table 2. As can be seen from Table 2, the neighborhood density of commercial vitality in the main urban area of Kunming City shows a positive correlation in general, indicating that the higher the density, the easier it is to cluster together.

Table 2: Moran Index GMI results.

	Moran's I	Z-score	P-value
Total Business Points	0.638	40.715	0.000

Based on the global Moran index, the analysis of commercial point density in each grid using the Local Moran's I (LMI) can provide insights into the spatial agglomeration and differentiation patterns of commercial points within the grid. Figure 4 depicts that high-high (H-H) density zones of commercial points are concentrated in the core area of the main urban area of Kunming City (Cuihu area) and the second ring area in the southeast direction. Additionally, a few low-high (L-H) zones are scattered within this area, while both H-H and L-H zones appear in smaller numbers in the southeast direction of the new urban district, suggesting the presence of a secondary core area for commercial activity in that region (Century City area). On the other hand, low-low (L-L) zones are primarily distributed in the new urban district outside of the southeastern region. To summarize, the most prominent concentrations of commercial activity in the main urban area of Kunming City are observed in the core area and the second ring road area, with a secondary core area in the southeast of the new urban district. This indicates that the density of commercial establishments exhibits the highest spatial variability in the core area and the second ring road area.
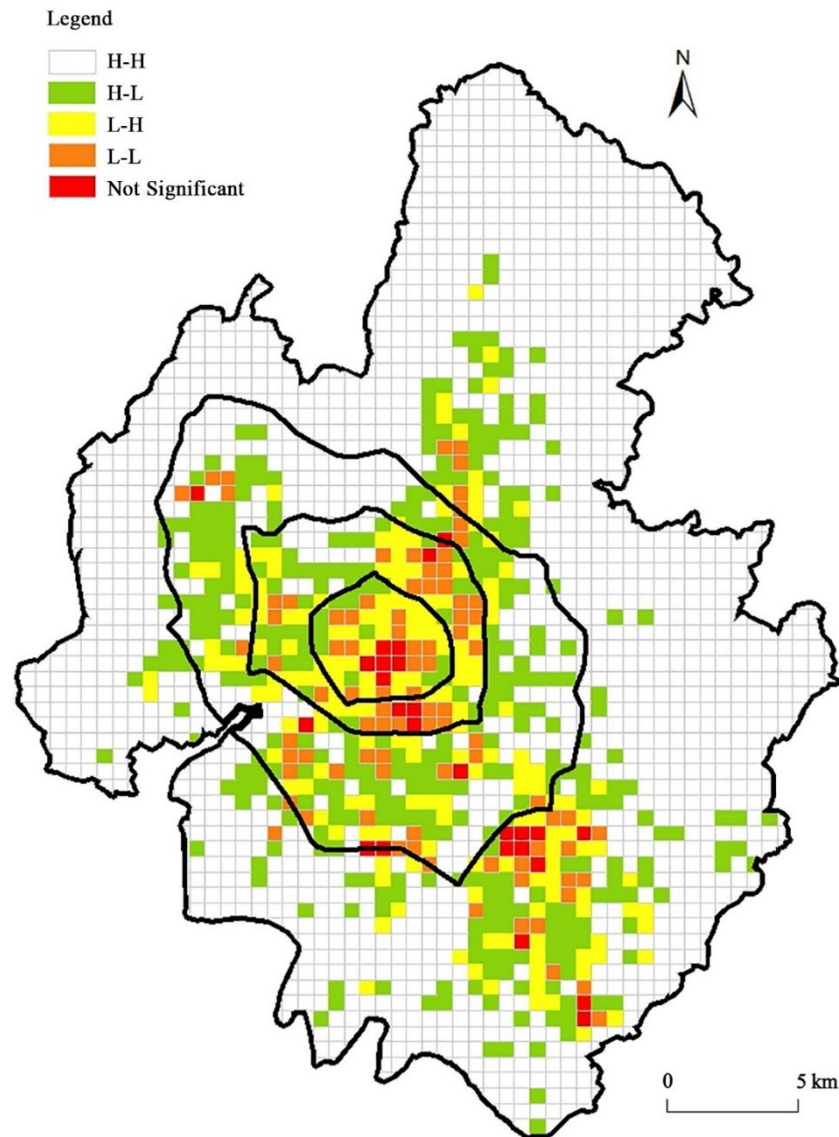
Figure 4: Spatial pattern of commercial point density in the main urban area of Kunming City.

4. Conclusions

In this study, the spatial differentiation pattern of commercial vitality in the main urban area of Kunming City was analyzed by using geographic information systems such as kernel density estimation, and average nearest neighbor distance analysis. The results show that (1) POI data accurately captured the spatial distribution information of outlets on a large scale, allowing for the analysis of the spatial structure of commercial vitality within the city. (2) The spatial distribution of commercial vitality in the main urban area of Kunming City is not balanced, and the spatial distribution of commercial vitality in the core area of the urban area differs greatly from that outside the first ring road, with a high degree of aggregation of commercial vitality in the core area, but there is also a distribution of secondary areas of high-value commercial vitality outside the first ring road. (3) The results of the GIS-based study show that the hotspots of commercial vitality in the main urban area of Kunming City are mainly concentrated in the core first ring area (Cuihu area) and the second and third rings, as well as the southeast area of the new urban district (Century City area).

Acknowledgement

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