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Hotspot Detection and Spatiotemporal Evolution of Catering Service Grade in Mountainous Cities from the Perspective of Geo-Information Tupu

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Abstract: Catering services are an essential part of urban life. The spatial structure and evolution of catering services can reflect the characteristics of an urban structure to a certain extent. In this study, we selected the main urban area of Chongqing, a typical mountainous city, as the research area. According to data sources for 200,000 catering POI data points in 2015 and 2020, we extracted the hotspots according to catering service grade based on kernel density. We quantitatively analyzed the spatiotemporal structure of catering services in the mountainous city. In addition, we used digital field hierarchical structure Tupu and generalized symmetric structure Tupu to identify the spatial morphology and evolution characteristics to enhance the understanding of geoscience trends. The results showed that (1) the distribution of catering services was statically consistent with the "multi-center group" distribution of the mountainous city and dynamically similar to the "sprawling leap" development of the mountainous city where it developed from independent points to cross mountains and rivers. Moreover, we found that there was a tendency of adhering development between groups. (2) From the perspective of symmetrical distribution, the symmetrical distribution of the catering industry reflected a certain generalized symmetrical structure with mountains and rivers in the mountainous city. Furthermore, the city tended to develop symmetrically along the topography, thus forming the symmetry of economic geography.

Keywords: POI; mountainous city; hotspots of catering services; spatiotemporal structure; Geo-information Tupu

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1. Introduction

At present, research on the spatial functional structure is an important part of urban research [1]. The catering industry is a key component of urban life. The spatial distribution characteristics and spatiotemporal evolutionary trends of the catering industry can reflect the function and structure of urban space, as well as the evolutionary characteristics of the development of hotspots to a certain extent. This information is important for urban development and business management. With the rapid development of spatial information technology, it has become easier to obtain complete data for urban service facilities [2]. Big data technology has increased awareness of the data-intensive research paradigm [3], compared with the study of all kinds of spatial problems under traditional data [4–6], and the data and methods have been greatly enriched. Scholars are increasingly studying urban spatial issues by obtaining internet map information of points of interest (POIs) and microblog check-ins. Catering services, as a specific interest point that are closely tied to urban life and that account for a large proportion, hold great value in the research of urban space.

At present, scholars have explored various aspects by using POI data. From the point of view of research and application purposes, some scholars have explored the location and sales forecasts of the retail industry [7,8]. Some scholars calculated the retail center area and customer source area from the data [9], to analyze the user characteristics of Twitter and Flickr [10]. Then, some scholars combined POI data with land utilization data for research [11]. In the exploration of analysis methods based on POIs, a graph theory-based localized contour tree method [12] is extended to the identification of urban polycentric structure with POIs as the data source [13]. In addition, densi-graph [14] and H/T breaks methods [15] were proposed to extract urban built-up areas successively. Additionally, a kernel density estimation method for estimating the density of points on a network was also proposed and can be used to identify hotspots such as traffic accidents and street crimes [16]. At the same time, scholars have carried out various explorations on the catering space, such as classifying cities according to catering [17], studying the interactive relationship between catering and other elements [18,19], and exploring the catering space and its evolution law [20–23]. In recent years, Chinese researchers have begun to pay attention to the regional differences and landscape spatial characteristics of urban catering taste and catering culture [24–26]. Additionally, they have studied the catering spatial distribution pattern [27–30], evolutionary characteristics [31,32], catering spatial characteristics [33], and location influencing factors [34,35].

Geo-information Tupu has been regarded by academic circles as a methodology of geographical science with unique oriental thinking characteristics. Since academician Shupeng Chen first proposed this theory and method, some scholars have carried out various explorations in urban information Tupu [36,37], urban form [38–40], land utilization [41–44], landscape pattern [45], hydrology [46], and topography [47] based on Geo-information Tupu. Geo-information Tupu has unique value in revealing the spatial pattern, evolution process, and element interaction mechanism of geoscience phenomena, and has the ability to reconstruct the geographical environment, evaluate the current situation, and predict the future [48].

To sum up, the research on the spatiotemporal pattern of the catering industry based on POI data has been limited mostly to application analysis and has less often been combined with the background of specific urban problems and data characteristics. In univariate analyses, most studies are based on simple density mapping and statistical methods, which lack quantitative analyses to further deepen the method. Furthermore, most of the time series are based on a single year. There are few studies on the spatiotemporal pattern of catering services in mountainous cities. Therefore, in order to make up for the deficiencies of all kinds of research mentioned above, we selected the main urban area of Chongqing, a typical mountainous city famous for its cuisine, as the research area, and the analysis period is 2015–2020. We extracted the hotspots from the density map by extracting the mountain vertex to fully divulge the information that the kernel density could display. This showed the distribution of five grades of the catering hotspots and vividly exhibited the development and correlation of hotspots. Compared with the widely used DBSCAN spatial clustering method [33], the hotspot extraction based on the kernel density method was more convenient and efficient. We introduced the theory and method of Geo-information Tupu, and three-dimensionally analyzed the spatiotemporal pattern of catering services using discrete generalized symmetrical Tupu and continuous digital field hierarchical structure Tupu by combining the time dimension with the two-dimensional plane. The study is important for the extraction of urban spatial hotspot elements and the analysis of urban structure and evolution characteristics. The study also presented a new idea for the formulation of urban planning. On the other hand, compared with plain cities, the pattern of catering services in mountainous cities is more complex and specialized because of the influence of mountains and rivers [49]. Research on mountainous cities can help us better understand the distribution trends of the catering industry in complex environments with both mountains and rivers. The research can guide the formation of benign interactions between the industrial layout and urban space and can inform the construction of mountainous cities.

2. Data and Methods

2.1. Study Area

Located in Southwest China, Chongqing is the only municipality directly under the central government in the west. It is the economic center of the upper Yangtze River and is one of the fastest growing cities in recent years. The year-end resident population of Chongqing was 31.2432 million in 2019 and 30.1655 million in 2015. In this study, we selected the main urban area of Chongqing as the research area, which is representative of a typical mountainous city. Jinyun Mountain, Zhongliang Mountain, and Tongluo Mountain are embedded in the area. The Jialing River and Yangtze River flow through the mountains from west to east, forming a complex landscape pattern of "two rivers, four mountains, and three trough valleys" with a "multi-center group" as the urban structure. The main city of Chongqing encompasses Yuzhong District, Jiangbei District, Dadukou District, Nan'an District, Shapingba District, Jiulongpo District, Beibei District, Yubei District, and Banan District with a total area of 5472.68 km2. In 2019, the catering revenue in Chongqing reached RMB 142.322 billion, up 13.6% and accounting for 16.4% of the total retail sales in the city. In the first half of 2019, Chongqing was listed in the growth rate ranking of catering revenue in certain cities as second only to Chengdu, which ranks second in all of China. The concept of a "group" is closely related to the urban spatial structure of Chongqing and plays an important role in the urban spatial performance of Chongqing. Therefore, we will take "group" as an important unit for analysis and description in the following part. In addition, the main urban area of Chongqing is divided into 21 groups in the Chongqing Urban and Rural Master Plan (2007–2020). In the Chongqing Urban and Rural Master Plan (2019–2035), the main urban area is divided into nine groups (Figure 1).

2.2. Data Sources and Processing

We obtained the data for this study from the POI data of Amap (Amap is a leading provider of digital map content, navigation and location services in China. https://lbs.amap.com/api/webservice/summary/, accessed on 1 January 2021) in December 2015 and March 2020. After repeated point removal and coordinate correction, we obtained 69,639 catering data points in 2015 and 130,414 data points in 2020, covering all restaurants, pastry shops, and beverage shops that could be found on Amap with clear classification in the research area. According to the POI classification code of Amap, the first-level classification includes 10 categories, and the second-level classification includes 65 subdivision categories (Table 1).

2.3. Construction of Service Hotspot Grade Map

2.3.1. Generation of Density Surface

The first law of geography holds that everything is related to other things, and things close to each other have a close relationship [50]. On the basis of this theory, the kernel density decreases with an increase in the distance radiating from the center point. The kernel density analysis takes the regular area around any spatial point as the range to calculate the density and analyzes the distribution of the research objects in the area through the density calculation. This method is often used to detect urban spatial hotspots [36,37]. The equation can be expressed as follows:

$$f(s) = \sum_{i=1}^{n} \frac{1}{h^2} k(\frac{s - c_i}{h}) \tag{1}$$

where $f(s)$ is the kernel density function at any spatial point; h is the distance attenuation threshold (aka bandwidth); n is the number of point elements within the bandwidth; $s - ci$

is the space distance between a point *ci* and the center point *s* in the bandwidth; and *k* is the spatial weight function. Moreover, both *h* and *k* are two important parameters in the kernel density estimation. It is necessary to determine a reasonable bandwidth as relevant studies have shown that bandwidth has a principal impact on the precision of the results. In this study, we reconstructed the density surface of restaurant POIs according to this method.

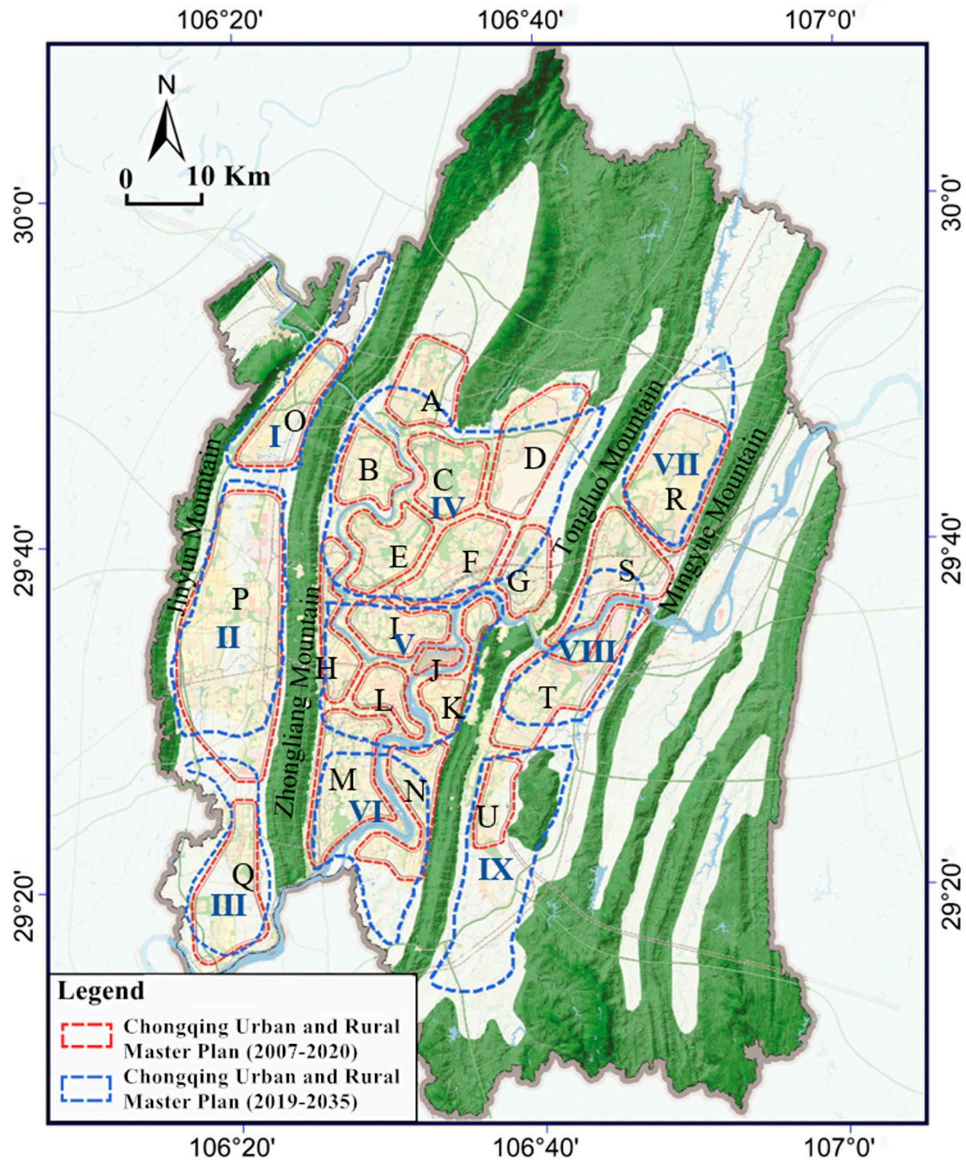


Figure 1. Study area A~U in Figure 1 and Figure 8 are same as Figure 1. Chongqing Urban and Rural Master Plan (2007–2020): A, Shuitu group; B, Caijia group; C, Yuelai group; D, airport group; E, Lijia group; F, Renhe group; G, Tangjiatuo group; H, Shapingba group; I, Guanyinqiao group; J, Yuzhong group; K, Nanping group; L, Dayangshi group; M, Dadukou group; N, Lijiatuo group; O, Beibei group; P, Xiyong group; Q, Xipeng group; R, Longxing group; S, Yuzui group; T, Chayuan group; U, Jieshi group. Chongqing Urban and Rural Master Plan (2019–2035): I, Beibei group; II, Xiyong group; III, Taojia group; IV, Northern group; V, Center group; VI, Southern group; VII, Longsheng group; VIII, Chayuan group; IX, Nanpeng group.

2.3.2. Obtainment of Catering Service Grade Hotspot

To quantify the expression and launch the structural analysis, we conducted further research on the basis of kernel density to extract catering service grade hotspots by means of the mountain vertex. Data processing in this study was completed by using ArcGIS software. First, we estimated the kernel density of the POI data to construct the density surface. We selected a reasonable bandwidth according to the needs of the analysis results. Second, we obtained the extremum of neighborhood pixels using neighborhood statistics. We obtained the non-negative surface by using map algebra between the density surface and the extremum of neighborhood pixels to obtain the local maximum peak value. In the non-negative surface, the zero value was the local peak value, whereas the non-zero area was the area with less than the peak value. Last, the peak value was extracted by the reclassification algorithm. Then, we extracted the original kernel density value by the peak point and classified the hotspots according to the original value (Figure 2).

Table 1. Classification of catering service POI data.

	First Class	Number of Second Class	Type of Second Class	Proportion (%)	
				2015	2020
1	Chinese restaurant	24	Comprehensive, Sichuan cuisine, Northeast cuisine	61.83	51.97
2	Foreign restaurant	18	Americancuisine, Japanese and Korean cuisine, Indian cuisine	1.59	1.69
3	Fast food restaurant	12	KFC, McDonald's, Yonghe Soy Milk	6.06	11.45
4	Leisure catering	1	Leisure catering places	0.39	0.18
5	Café	5	UCC Ueshima, Starbucks	1.92	1.19
6	Tea house	1	Restaurants featuring tea art	6.75	4.66
7	Cold drink shop	1	Beverage shops with cold drinks	0.89	1.34
8	Pastry shop	1	Shops featuring various kinds of pastries in China and abroad	2.29	1.95
9	Dessert shop	1	Shops featuring desserts	1.54	0.52
10	Catering-related place	1	Other physical restaurants registered on Gaud Map	16.74	25.06

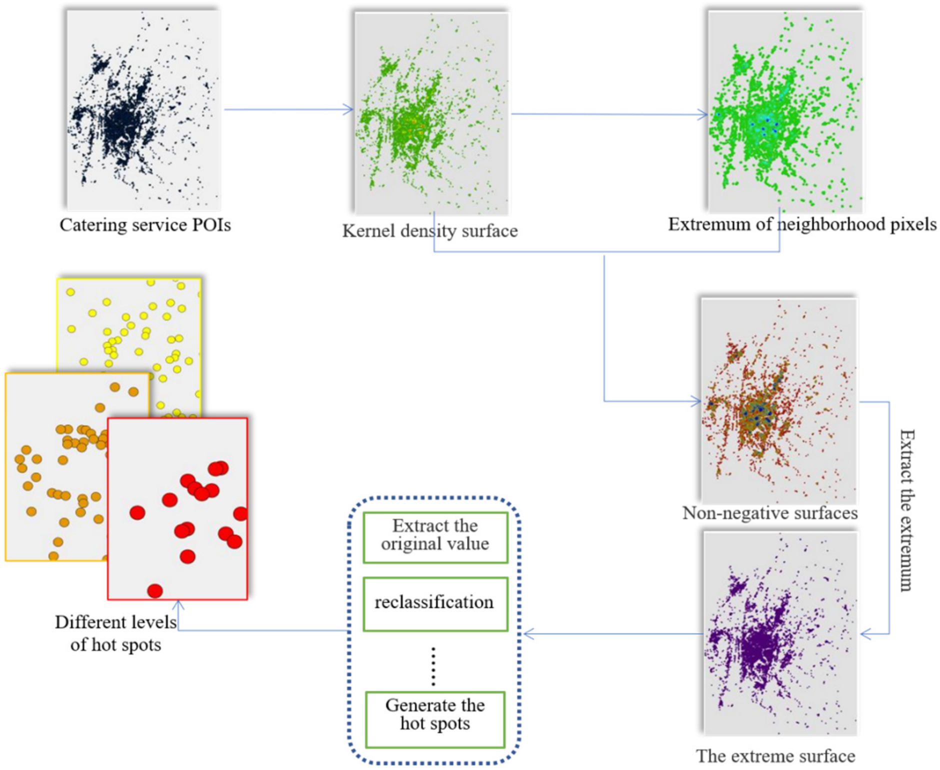


Figure 2. Access to hotspots of each catering grade.

For this article, we used 71,400 POIs in 2015 and 132,300 POIs in 2020 to extract the mountain vertex of the density map on the basis of kernel density processing. We selected a variety of bandwidths from 100 m to 1000 m for this test. After many comparisons, we found that the bandwidth below 200 m was too scattered and contained too many primary hotspots, the bandwidth between 300 m and 500 m was relatively stable, and the bandwidth larger than 600 m was too comprehensive. Finally, we selected 300 m as the bandwidth to extract the catering service grade hotspots. The pixel size was set to 10 m to ensure enough resolution. According to the original kernel density value of POI, we used the Jenks natural breaks [51] classification method to reclassify and divide the catering hotspots into five grades. The "natural breaks" identify the classification interval, group the similar values most appropriately, and maximize the differences between different classes, which is exactly in line with the hotspot classification criteria in this paper. The five grades of catering hotspots are divided into large catering service hotspots, medium–large catering service hotspots, medium catering service hotspots, medium–small catering service hotspots, and small catering service hotspots. Moreover, we divided the classification of catering service hotspots in 2020 according to the reclassification standards in 2015 to highlight the evolutionary characteristics of catering service hotspots.

2.4. Spatial Structure Analysis Method

Geo-information Tupu adopts the graphic thinking mode of a spectrum and further develops the ability for quantitative and simulation analysis [52]. In the field of geosciences, Geo-information Tupu is an effective method to understand and describe complex geographical phenomena and issues. Additionally, Geo-information Tupu can deepen the summary, extraction, expression, and application of geographical trends. Among the various forms of Geo-information Tupu, the hierarchical structure Tupu and generalized symmetric structure Tupu are the most widely applied [53]. Both are suitable for the expression and analysis of the distribution characteristics and spatial patterns of catering service grade hotspots in this study. Hence, we analyzed the spatial structure of catering service grade hotspots using two kinds of Geo-information Tupu.

A hierarchical structure can be used to extract the hierarchical relationship in geographical phenomena and reveal the spatial trends of scale attributes. The digital field hierarchical structure Tupu models the spatial distribution characteristics of a geographic object and the number of an attribute value expresses the topological relationship of elements in space by digital field, and expresses the hierarchical relationship between elements by a hierarchical tree structure (Figure 3). In this paper, the isodensity digital atlas is constructed according to the kernel density map generated by POIs, and the large catering service hotspots are taken as the node (the first grade). According to the hierarchical relationship contained in the isodensity digital atlas, an isodensity hierarchical tree is constructed to study the spatial topological relationship. The generalized symmetric structure Tupu broadens the establishment conditions of traditional geometry and extends the symmetric structure to the spatial symmetry of geographical objects. We explained translational symmetry, antisymmetry, and color symmetry based on traditional axial symmetry, central symmetry, and rotational symmetry. We used this approach to analyze the characteristics of the urban spatial distribution (Figure 4) [54]. Figure 4a–c are crystallographic symmetries. We added translational symmetry to illustrate the distribution trend of cities along rivers, highways, and railways (Figure 4d). Parallelograms have often been seen in maps. Traditional geometric symmetry, however, cannot describe its symmetry state. Therefore, we introduced oblique symmetry (Figure 4e). Crystallographic symmetry is linear symmetry. Yet, in reality, the geographical phenomenon is often curvilinear. Therefore, we extended urban geographical symmetry to curvilinear symmetry (Figure 4f). These symmetries involve only geometric symmetries and do not involve differences in matter and quantity. Thus, we introduced antisymmetry (Figure 4g) and color symmetry (Figure 4h). Antisymmetry is different from asymmetry. The Earth's land and sea are antisymmetric. For instance, the Arctic Ocean and Antarctica are antisymmetrical and have the largest scale on Earth. In addition, regional economic development greatly depends on the natural conditions of the region. A region with asymmetric natural conditions cannot develop into a completely symmetrical economic pattern. The significant differences in regional economic development resulting from various causes are called the color symmetry of an economic pattern. Generalized symmetry is formed after extending this concept of symmetry.

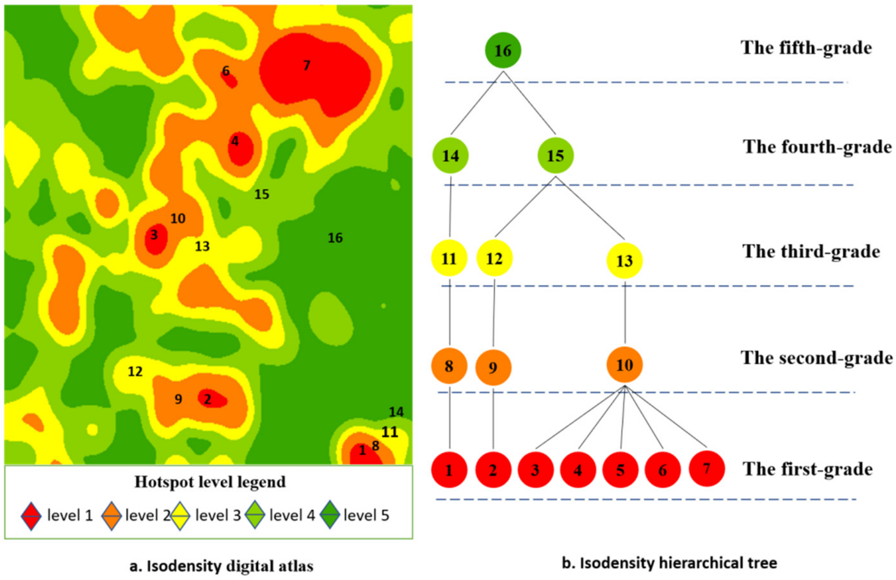


Figure 3. Digital field based hierarchical Geo-information Tupu. (**a**) Generate isodensity digital altas from kernel density map; (**b**) Extract the eigenvalues of isodensity digital atlas to generate isodensity hierarchical tree.

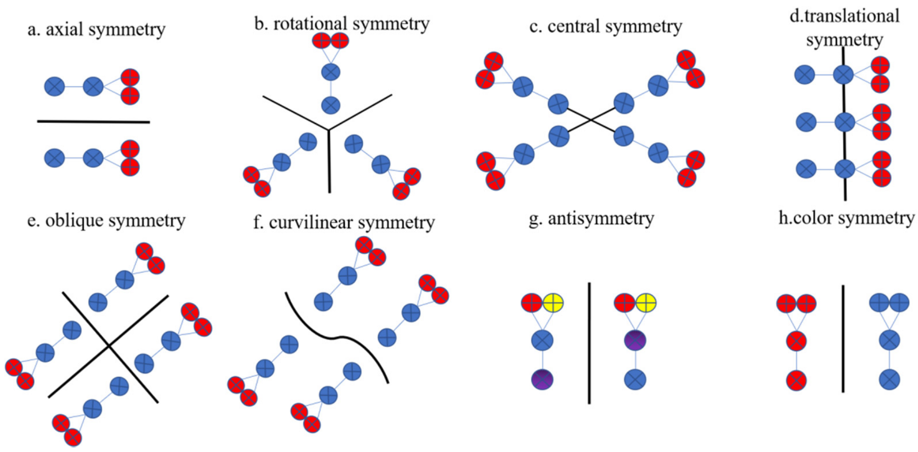


Figure 4. Geo-information Tupu of generalized symmetric structure. (**a**–**h**) are the eight common symmetric structure.

3. Results

3.1. Urban Catering Service Hotspot Detection and Time Series Comparison

The number and proportion of hotspots in each grade of catering service after extraction are shown in Table 2. Figure 5 shows the distribution of hotspots in 2015 and 2020. According to the information in Table 2 and Figure 5, there were six large catering service hotspots in 2015, accounting for only 0.51% of all service hotspots. This indicated that the distribution of large catering service hotspots was relatively scattered. All of these hotspots were within the inner ring, forming a star-shaped distribution trend with Daping as the center. In 2020, the grade and scale of catering service hotspots developed significantly and formed 21 large catering service hotspots, accounting for 1.50% of the total. The Xiyong group, Beibei group, Lijiatuo group, and Dayangshi group each added one large catering service hotspot. The airport group developed three large catering service hotspots. Within the inner ring, Daping, Guanyinqiao, Shapingba, Yangjiaping, Nanping, and Jiefangbei no longer formed a star-shaped structure centered on Daping, but rather formed a cluster structure in the center group with the development of many large and medium service hotspots. The large catering service hotspots generally were the most prosperous, crowded, and traffic-intensive areas in the city and were affected by multiple core driving factors. In 2015, there were 44 medium–large catering service hotspots, accounting for 3.81% of the total. In 2020, there were 81 hotspots, accounting for 5.81% of the total, almost double that in 2015.

Table 2. Basic attributes of catering service in different hierarchical levels.

Grade of Catering Service Hotspots	Quantity		Proportion		Mean Density	
	2015	2020	2015	2020	2015	2020
Large	6	21	0.51%	1.50%	4772.47	4616.21
Medium to large	44	81	3.81%	5.81%	1656.04	1729.55
Medium	74	139	6.41%	9.98%	924.38	894.49
Medium to small	171	259	14.81%	18.60%	401.71	406.69
Small	859	892	74.43%	64.08%	41.88	44.24

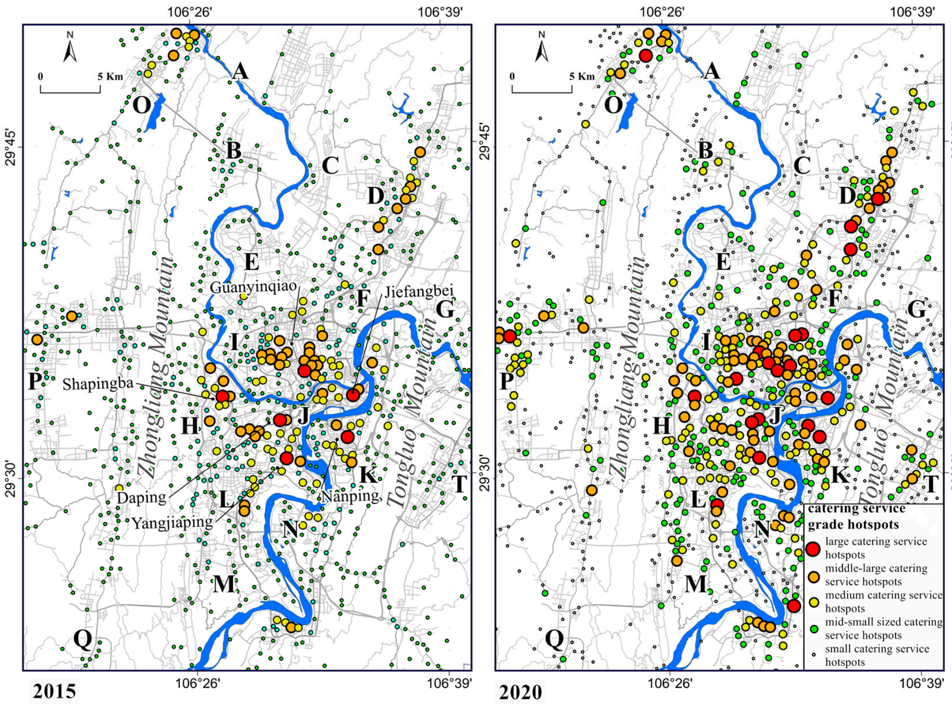


Figure 5. Hotspot distribution.

We found that the medium–large size catering service hotspots were locally concentrated and multi-core distributed compared with the distribution of hotspots over the past two years. This could explain the development of local areas to a certain extent. Accounting for more than 90% of the total, lower grade catering service hotspots were found in large numbers and scattered, which we used to analyze the urban morphology and evolutionary factors. By comparing the average density values of adjacent grades, we found that the values dropped several fold as the grade decreased. In addition, the mean density values of the hotspots in each grade were significantly different, which reflected the trend of internal grade formation.

3.2. Analysis of Urban Structure and Evolution Based on Catering Service Hotspots

3.2.1. The Perspective of Generalized Symmetric Structure Tupu

We present the distribution trend of catering service hotspots according to different grades with a generalized symmetrical structure Tupu of urban geographical symmetry. We identified six large catering service hotspots in 2015. All were distributed in the center group. The numbering of catering service hotspots follows that of the previous section. A total of six large catering service hotspots formed an axisymmetrical structure (Figure 6a).

Taking Yuzhong Peninsula or the two-river symmetry axis as the line, this region passed exactly through the No. 2 and No. 4 hotspots. Taking this line as the symmetry axis, the No. 1 and No. 3 hotspots were symmetrically distributed with the No. 6 and No. 5 hotspots, respectively. In practice, however, Figure 6a reveals that the center group was distributed along the Yuzhong Peninsula in an axial symmetry. In addition, this symmetry was further expanded and enriched in 2020. As shown in the 2020 figure, the axis of symmetry formed a straight line including the No. 2, No. 14, and No. 4 hotspots (Figure 6b). The No. 1, No. 7, No. 9, and No. 3 hotspots were axisymmetrical with the No. 15, No. 6, No. 5, and No. 13 hotspots, respectively. The No. 8, No. 10, No. 11, and No. 12 hotspots could not be axisymmetrical with Yuzhong Peninsula mainly because the Nanping group was blocked by Tongluo Mountain. As a result, it could not continue to expand. The evolution of the symmetrical axis in Yuzhong during these two periods indicated that the saturated development trend of the trough valley area in central Chongqing with Yuzhong formed a symmetrical axis in the center of the groups. Meanwhile, the hotspot areas of smaller groups within the center group formed a symmetrical structure along the two rivers. For example, the service hotspot area of the Nanping group and Guanyinqiao group formed a color symmetry because of the unequal development level (Figure 6c). There were only two large hotspots in the Nanping group and there were five in the Guanyinqiao group. The fundamental reason for the different capacities and color symmetry of the two groups could be attributed to the influence of topography. The Nanping group was double blocked by the Yangtze River and Tongluo Mountain. The entire Guanyinqiao area, however, is relatively flat and without a mountain barrier. There was enough space for development. Therefore, the development scope and trend of Guanyinqiao were better than that of the Nanping group.

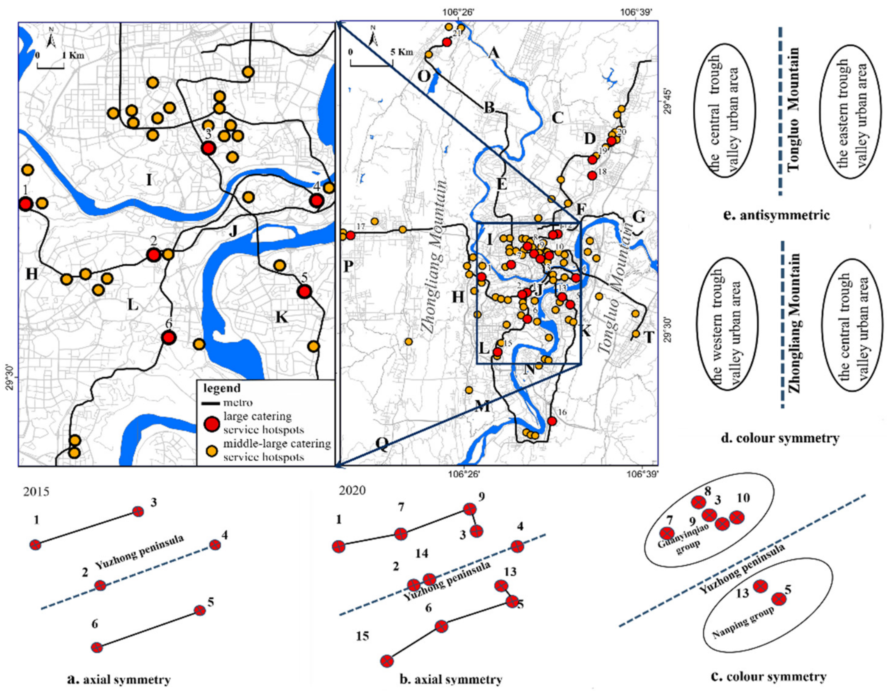


Figure 6. The extraction results of Geo-information Tupu of generalized symmetric structure for the largest scale catering service hotspots. The range of 2015 is the range of the box in 2020. (**a**–**e**) are several symmetric structures extracted.

According to the four mountains and three trough valleys, we divided the main urban area of Chongqing into the eastern trough valley urban area, the central trough valley urban area, and the western trough valley urban area. Combined with the distribution of large and medium–large catering service hotspots in the main urban area of Chongqing, the main urban area of Chongqing presented a color symmetrical and antisymmetrical structure, with Zhongliang Mountain and Tongluo Mountain as the symmetrical axis. In 2015, there were only five medium–large size catering service hotspots in the western trough valley urban area to the west of Zhongliang Mountain, whereas all other large and medium–large catering service hotspots were distributed in the central trough valley urban area between Zhongliang Mountain and Tongluo Mountain. In addition, there were no mature large or mid-sized catering service hotspots in the eastern trough valley urban area to the east of Tongluo Mountain. After five years of development, there were two large hotspots and eight medium–large size hotspots in the western trough valley urban area but only three medium–large size catering service hotspots in the eastern trough valley urban area. The two trough valleys with Zhongliang Mountain as the symmetrical axis always presented a state of color symmetry because of the unequal capacity of the catering service hotspots (Figure 6d). Conversely, the two trough valleys with Tongluo Mountain as the symmetrical axis developed only from antisymmetry to color symmetry with significant differences (Figure 6e). The development vitality of trough valleys on both sides remained low, creating a phenomenon where the development of the trough valley in the middle was relatively mature, and the development of the trough valley in the east and west was relatively behind. The development of the trough valley in the west, however, was better than that in the east [55,56]. Nevertheless, it was sufficient to display the growing development trend of Chongqing from the core area of the two rivers and four banks across the mountains and rivers.

3.2.2. The Perspective of Digital Field Structure Tupu

As the most concentrated region of catering POIs, the first-grade catering service hotspot represented the regional center of the city. The hierarchical tree adopted the critical value of the 2015 catering grade division to ensure the consistency of the five-year change and hotspot division. The increase in the number of catering spots in 2020 was based on the number of the six catering spots in 2015. Each spectrum contained five hierarchies in the 2015 digital field hierarchical structure Tupu. The layout of the six first-grade hotspots was scattered and highly independent in 2015. Those hotspots did not gather until the fifth hierarchy. Through five independent branches, the multi-center group urban structure was clearly illustrated (Figure 7). In 2020, there was a sharp rise in the number of first-grade hotspots. Among these first-grade hotspots, the No. 2 and No. 14 hotspots converged into the No. 23 hotspot in the second hierarchy and then converged with the No. 4 hotspot through node 54 in the fourth hierarchy. The No. 8, No. 9, No. 3, and No. 10 hotspots converged into the No. 27 hotspot in the second hierarchy and then connected with the No. 28 hotspot, which converged with the No. 11 and No. 12 hotspot, to converge into node 57 in the fourth hierarchy after two independent grades. The No. 5 and No. 13 hotspots with the No. 19 and No. 20 hotspots appeared to have an agglomeration phenomenon at the research scale in the third and fourth hierarchies, respectively. The other eight first-grade hotspots remained independent in the different hierarchies (Figure 8). The reason for this hierarchical tree structure was that Chongqing, as a typical mountainous city, had four mountains, two rivers, and three valleys, which led to incoherent terrain. Furthermore, the development of the mountainous city was blocked by mountains and rivers. Consequently, it could form a multi-center group [57] development mode. By analyzing Figures 6–8, we found that only the No. 2 and No. 6 hotspots belonged to the Dayangshi group whereas the others each belonged to separate groups in 2015. With the development of large and mid-sized catering service hotspots, groups in Beibei, Xiyong, Dadukou, and Lijiatuo each grew into one large catering service hotspot in 2020. They still lagged behind in development. The Beibei group and Xiyong group lacked development impetus because of the connection barrier between Zhongliang Mountain and the central urban area. In contrast, the airport group had the fastest rate of development. This group developed three large catering service hotspots and eight medium–large catering service hotspots from many medium–small catering hotspots. In addition, the three first-grade catering service hotspots in the fourth and third hierarchies had the tendency to form belt convergence development through medium–small size catering service hotspots according to the contour line. After five years of development, the Guanyinqiao group grew to include five first-grade catering service hotspots, which connected the entire group in the fourth hierarchy through many medium–small catering hotspots and associated with Renhe group in the fourth hierarchy. Chongqing merged 21 groups into nine groups in 2019. The center group included the Guanyinqiao group, Yuzhong group, Dayangshi group, Nanping group, south of Renhe group, south of Shapingba group, north of Dadukou group, and one corner of Lijiatuo group. Interestingly, the center group in 2020 included first-grade catering service hotspots from the No. 1 to No. 15 hotspots, which connected most of the areas in the center group through low-grade hotspots in the fourth hierarchy of the spectrum, which show a significant phenomenon of "multi-point connection" [58]. The internal development of each group was toward the direction of integration. The "adhered" development trend between groups caused by the phenomenon of multi-point connection, however, should be given attention. Moreover, the low-density and disorderly sprawling development of groups should be strictly prevented. Additionally, both disorderly development inside the barrier and slow development outside the barrier should be prevented.

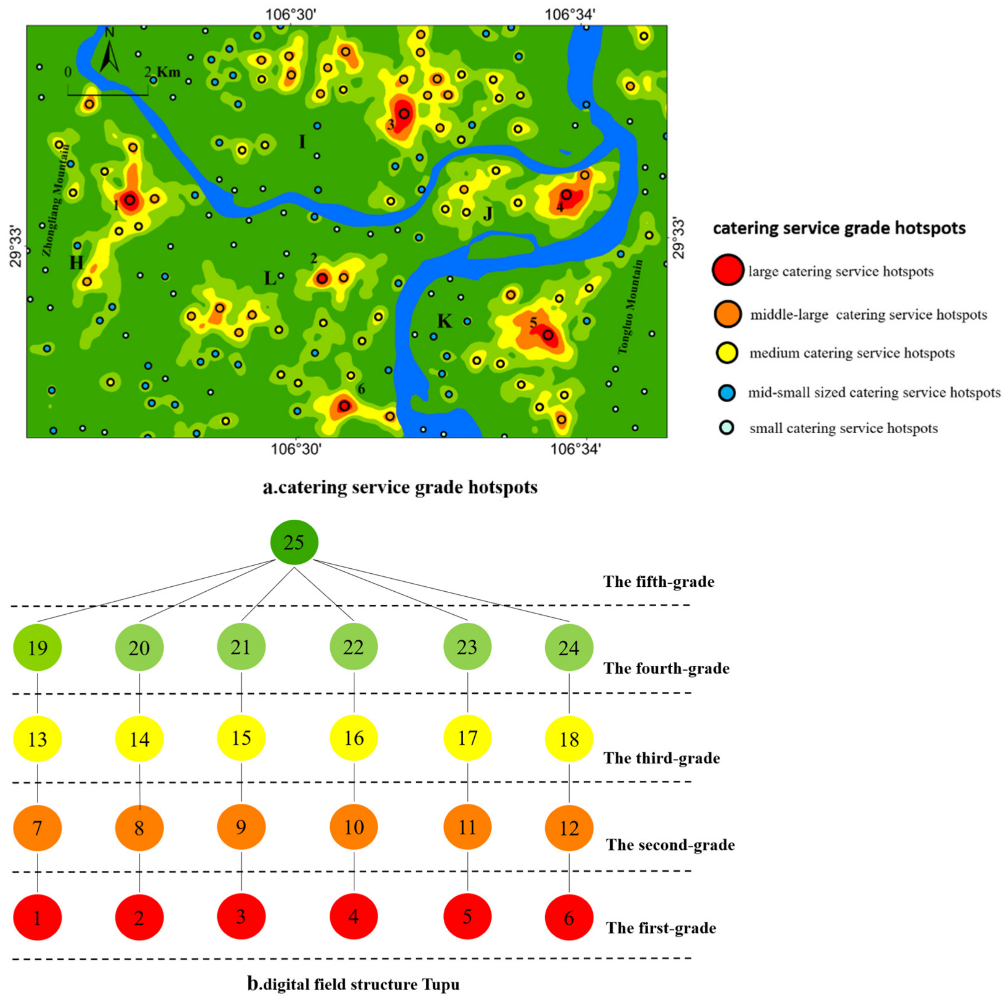
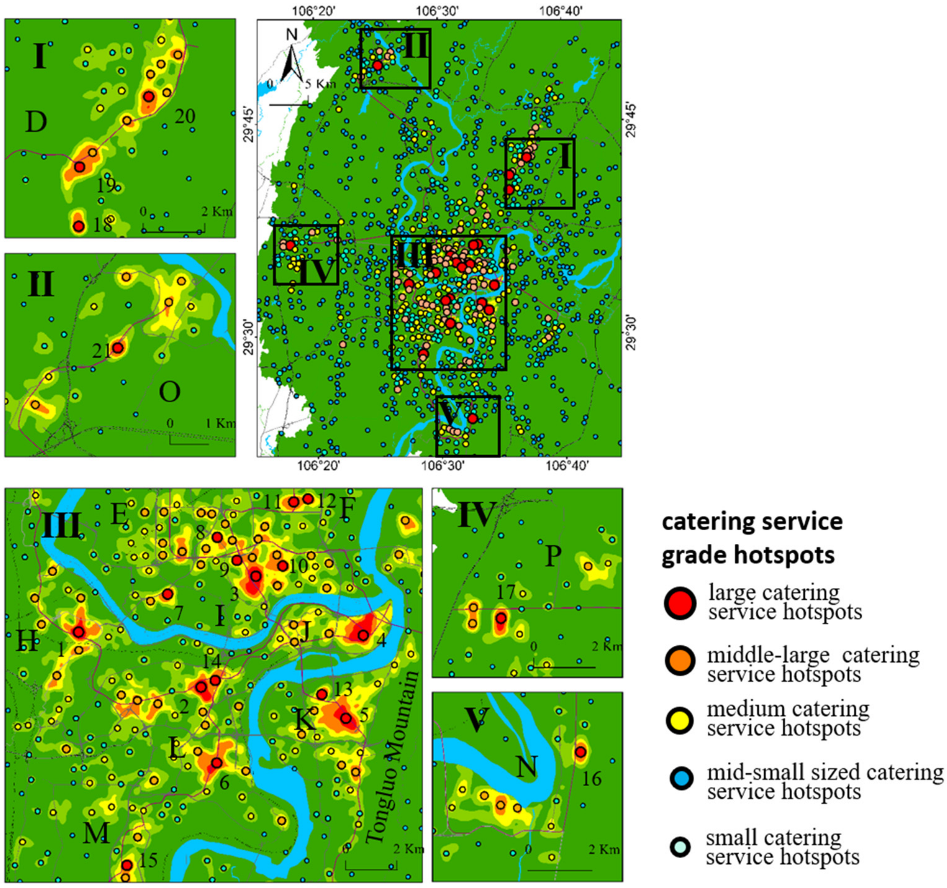
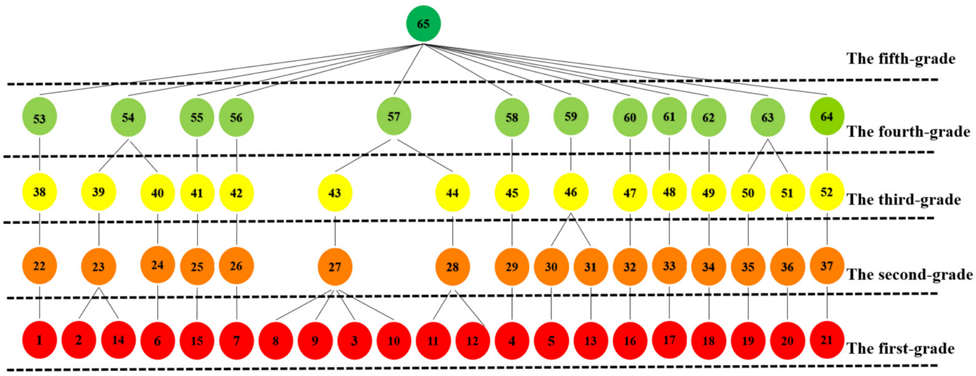


Figure 7. The extraction results of digital field-based hierarchical Geo-information Tupu in the study area of 2015. (**a**) is the kernel density map and its generated catering service grade hotspots; (**b**) is the digital field structure Tupu generated by (**a**).



(**a**) catering service grade hotspots



(**b**) digital field structure Tupu

Figure 8. The extraction result of digital field-based hierarchical Geo-information Tupu in the study area of 2020. (**a**) is the kernel density map and its generated catering service grade hotspots; (**b**) is the digital field structure Tupu generated by (**a**).

4. Discussion

4.1. Thinking about the Results

The results of this study showed that the development of Chongqing's main urban area was imbalanced to a certain extent. Figure 6 shows that the central trough valley urban area is the most mature compared with the east and west trough valley urban area. The hotspots of the large and medium–large size catering services in the western trough valley urban area were concentrated mainly in the subway area that connected the central trough valley urban area. Therefore, transportation was a key factor in the development of the western trough valley urban area. Next, the Xiyong group in the western trough valley urban area had the strongest development vitality in both the eastern and western trough valley urban areas because of the existence of the university town. Although the Chayuan group in the eastern trough valley urban area was connected by light rail and was closer to the Yuzhong group than the Xiyong group, it still did not form a large catering service hotspot after five years of development. Additionally, there were relatively fewer low-grade hotspots. The development still did not break through the barrier of the mountains. It can be seen that the advantages of location and transportation are far from enough, and policy and human factors often played a greater role. The two groups of color symmetry formed by taking Zhongliang Mountain and Tongluo Mountain as the axis have not reached a relatively ideal state, perhaps because of the previous development policy being too biased toward the five centers within the inner ring, with the differences in supporting service facilities and transportation and commuting costs between the inner ring and the outer ring. For these reasons, a trend of adhering development occurred among groups that was driven by economic interests, especially in the center group area. Hence, the natural terrain could not be solely relied on to maintain the ideal urban structure of the "multi-center group" in Chongqing to avoid various urban problems caused by the imbalance between urban internal development and urban adhered development. Ultimately, a strengthened policy was needed to maintain the balanced development of the city and prevent the "adhered" development of the groups.

4.2. Merits of Proposed Methods

Taking the main urban area of Chongqing, which is a typical mountainous city, as the research area, we demonstrated the urban structure of Chongqing with the spatial structure of the catering industry by means of kernel density analysis, a hotspot grade map, and Geo-information Tupu based on catering POI data in 2015 and 2020. Compared with some foreign structure identification methods, such as exploratory spatial data analysis (ESDA) [4], locally weighted regression (LWR) [5], and proportional verification and spatial statistics [6], this research method has more advantages in visualization and structure. Next, compared with the current research on the urban structure of Chongqing, we innovatively analyzed the structure of Chongqing's main urban area and development hotspots from the perspective of symmetry. We identified the problems associated with the "adherence" development trends in the area of the center group in a simple and efficient way. In this study, Geo-information Tupu was used as the spatial structure analysis method. At present, there are urban morphology information Tupu [38], urban agglomeration interaction Tupu [39], and urban morphology evolution Tupu [40]. Most studies, however, are based on the macro-perspective of multiple cities or the whole urban morphology. There are few studies on urban interior or development hotspots from the micro-perspective, such as that used in this study. In addition, there are few studies from the perspective of time series. In this study, we used generalized symmetric structure Tupu to analyze the area of hotspots and urban patterns of the main city of Chongqing. We analyzed both the symmetric development with Yuzhong District as the axis and the antisymmetrical and color symmetrical development of the new city and parent city from the mountain range. Moreover, most of generalized symmetrical structure Tupu is currently based on urban clusters or the province scale [36,37]. Yet, there are few studies on local hotspot areas. We presented the discrete aggregation and relationships of catering hotspots using digital field structure Tupu in the form of a hierarchical tree. This method is similar to the density contour tree [13]. Nevertheless, digital field structure Tupu offered more advantages in the description of urban discrete aggregation status and spatiotemporal evolution.

4.3. Limitations and Future Research

We introduced Geo-information Tupu, based on the catering POIs, into the study of urban hotspots and urban structure. As a result, we realized the quantitative description toward the structure of the mountainous city and enhanced the ability to analyze, interpret, and visualize of the spatial distribution pattern and relationship of hotspots. The introduction of time series clarified the catering structure and the evolution characteristics of urban structure. It not only reflected the spatiotemporal distribution of geological phenomena, but also revealed its spatial pattern and evolution process. There are still many shortcomings, even though we made progress compared with existing research. For instance, the selection of scale had a great impact on the research, while it was mostly based on experience when selecting the scale. As for data selection, we based our research on only single restaurant POI data while the application of multi-source data would also have been a good choice. This method can be widely used in the feature extraction and spatial structure analysis of all kinds of POIs and other point-intensive data. When applied to other cities or data, special attention should be paid to the selection of scale, which will have a great impact on the results. Secondly, it should be representative in the selection of data, otherwise it is not enough to represent the form and change of structure. This paper makes a detailed analysis of the hotspots of catering services and the characteristics of the spatiotemporal structure of the city. However, the exploration of the influencing factors for the development of the catering industry will also be of great significance in future research. Although some scholars have studied the influencing factors of catering service distribution [49,50], most of these studies were based on a certain year to study the influencing factors. Few analyses have examined the evolution of catering service distribution and the time series change of influencing factors, only considering their correlation in space. We think that this is not comprehensive, and the disturbance caused by the change of one factor to other factors may be more representative of their substantive relationship. The change of catering hotspot density must have some potential relationship with the change of surrounding business, transportation, housing, education, and medical sites. Time series analysis introduces a mechanism analysis similar to market regulation, so as to explore its correlation in the three dimensions of time and space. These studies will play an important role in the evaluation of the development of a certain industry and the upgrading and adjustment of the industry.

5. Conclusions

Catering services are closely related to the urban life of citizens, and are spread all across cities in the form of restaurants. Due to location certainty and quantity knowability, the layout of and changes in catering services are inextricably linked with the layout and evolution of a city. Catering, to a certain extent, can reveal the degree of development in local areas in a city and the relationship between the scale and geographic location of each area. Furthermore, catering can reflect the vitality and function of urban development. On the basis of catering industry POI data, we selected the main urban area of Chongqing, a typical mountainous city, as the research area. We introduced Geo-information Tupu on the basis of catering hotspot detection. We also made a three-dimensional analysis of catering in Chongqing and the mountainous city structure from a spatiotemporal perspective. The following are the main conclusions:

(1) The distribution and expansion of the catering industry is consistent with that of mountainous cities. From a static point of view, the distribution of the catering industry was affected by the landscape segmentation, which was consistent with multi-center group distribution in a mountainous city. From a dynamic point of view, the mountainous city was affected by complex landscapes. First, the catering industry developed in areas with relatively good conditions and formed many relatively independent hotspots. As time passed, these hotspots gradually broke through barriers of natural factors to establish connections and then made substantial development across mountains and rivers through tunnels and bridges. The multi-center city, however, was prone to producing development among groups during the development of multi-point connection. This type of development was not conducive to the sustainable development of the multi-center city. In addition, the development of the catering industry was relatively consistent with the expansion of the mountainous city. The degree of maturity of the catering industry in the parent city within a mountain barrier was much higher than that outside a barrier. This

formed a spatial pattern of density inside and sparseness outside the barrier, which had a similar layout to the expansion of the mountainous city.

(2) The distribution of the catering industry reflects the symmetry of the city. From the perspective of symmetrical distribution, the symmetrical distribution of the catering industry reflected that the mountainous city usually had a generalized symmetrical structure along with mountains and rivers. Meanwhile, the city usually developed symmetrically along the topography, thus forming the symmetry of economic geography, which was reflected in the symmetrical distribution of the city. The antisymmetry or color symmetry between the parent city and the new city that was formed by the mountain barrier would gradually develop into an ideal symmetry or color symmetry under the influence of traffic and policy. Therefore, it was conducive to political stability and regional sustainable development.

To sum up, the method and idea of this paper can be widely used in extracting hot elements of urban space and evaluating urban development situations and trends, providing a novel idea for urban development prediction and urban planning and, meanwhile, it is of great significance for the discovery and treatment of "adhered" development problems in multi-center cities.

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