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Spatio-temporal pattern evolution of residents' living space in Suzhou based on POI data

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Abstract: This study identifies the spatio-temporal pattern of urban development based on the POI data of the entire Suzhou area in 2013, 2018 and 2023, analyzes its distribution characteristics and evolution trends, and discusses the main factors influencing the urban spatial pattern of Suzhou, providing an important reference for the optimization of urban space in Suzhou. The research finds that from 2013 to 2023, the living space of residents in Suzhou City has the following characteristics: (1) The interest points as a whole show an agglomeration feature, but there is a diffusive development trend internally; (2) The overall distribution of residents' living Spaces is from northeast to southwest, and the development trend has not undergone significant changes over the past ten years. (3) According to the development center of the living space of Suzhou residents, it first moved to the southwest and then to the southeast, but was concentrated within the central urban area of Suzhou.

1. Introduction

In recent years, with the continuous development of big data technology, geographic big data represented by POI (Pointof Interest) data, with its massive data samples, has become a precise and detailed analytical tool. Point of interest (POI) data has been widely used to characterize urban Spaces because POI provides key information about the "space" and "attributes" of cities [1]. POI analysis can be conducted at various geographical scales, ranging from location [2] and block [3] [4] to regional [5] [6] and city levels [7]. POI has been widely applied in the mapping of urban functional zoning [5] [7]. With the expansion of the coverage and attribute dimensions of POI data, the distribution, density and combination of infrastructure can be measured on a large scale [8], and it is helpful to assess the allocation of public resources [9] [10]. In addition, a large number of studies analyze POI data through GIS to study the changes of urban space. Kucukpehlivan et al. analyzed POI through the kernel density estimation of GIS and confirmed the impact of public investment on urban space [11]. Li and Zhang used kernel density analysis and nearest neighbor index of GIS to analyze the spatial distribution of Tianjin scenic spots' POI [12].

Therefore, based on GIS technology, this study employs spatial analysis methods such as kernel density estimation, standard deviation ellipse, and nearest neighbor index, and uses POI data to explore the distribution and variation of urban living Spaces in Suzhou City.

2. Materials and Methods

2.1. Overview of the Research Area

Suzhou City is located in the eastern part of China. It borders Shanghai to the east and Zhejiang to the south. With a total area of approximately 8,657 square kilometers (34.6% of which is water), the terrain is low and flat, and the river network is dense. The geographical coordinates are located at 119°55' E to 121°20' E, and 30°47' N to 32°02' N. It governs five districts (Gusu District, Huqiu District, Wuzhong District, Xiangcheng District, Wujiang District), administers four county-level cities (Kunshan City, Changshu City, Zhangjiagang City, Taicang City), and also has Suzhou Industrial Park (SIP) (functional area) (Figure 1).

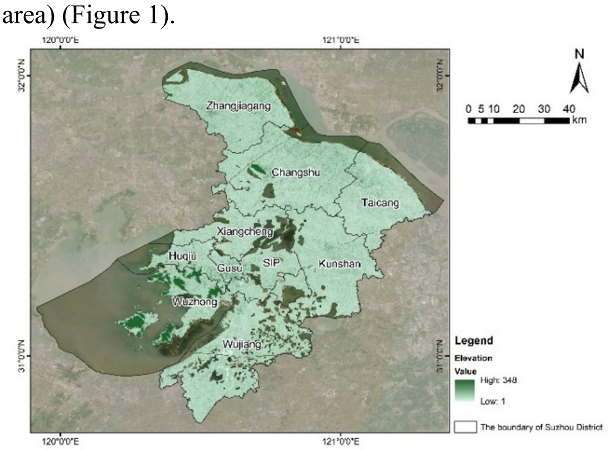

Figure 1. Location of the targeted area.

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2.2. Data source

The position of POI will change over time [13]. Therefore, this study obtained the POI data of Suzhou City through the API interface of Autonavi Maps. Based on the actual living conditions of residents, the above information was screened and classified to obtain the POI data set representing the functional points of living Spaces (Table 1).

Table 1. Reclassification results of POI data.

Spatial type	POI level 1 classification	POI level 2 classification
Resident Living space	Transportation facilities	Subway stations, railway stations, parking lots, etc
	Shopping service	Farmers Market, supermarkets, convenience stores, etc
	Catering and gourmet food	Tea houses, cake shops, snack and fast food restaurants, restaurants, coffee houses
	Accommodation service	Hotels, homestays, etc
	Science, education, and culture	Museums, archives, libraries, cultural palaces, scientific research institutions, radio and television stations, schools, etc
	Services for Living	Post office, lottery sales, express delivery, hairdressing, etc
	Leisure and entertainment	Cinemas, KTVS, bars, Internet cafes, amusement parks, etc
	Medical services	Hospitals, clinics, pharmacies, etc
	Sports and fitness	Courts and other venues, fitness centers, etc
	Park and green space	Parks, squares, zoos, botanical gardens, aquariums, etc

2.3. Research Methods

2.3.1 Kernel density Estimation method

The kernel density estimation method can directly reflect the degree of aggregation of POI in space. The higher the value, the higher the degree of aggregation of point elements in space, indicating that the regional data distribution is more concentrated.

2.3.2 Standard Deviation Ellipse Method

The standard deviation ellipse can reflect the spatial distribution characteristics of POI data through the ellipse direction, Angle, and axis length.

2.3.3 Average Nearest Neighbor Index Method

The average nearest neighbor index can be used to determine whether the POI is spatially clustered, dispersed or randomly distributed by calculating the average distance of the POI data.

3. Analysis of the Evolution Characteristics of the Spatio-temporal Pattern of Residents' Living Spaces in Suzhou

3.1. Analysis of Agglomeration Characteristics

3.1.1 Kernel Density Estimation Analysis

In 2013, the core agglomeration area of living space in Suzhou City was the Gusu District, while Changshu, Zhangjiagang, and Kunshan in the northeast region formed three agglomeration areas. In 2018, the agglomeration development area of living space in Suzhou moved towards Suzhou Industrial Park (SIP), and the trend of agglomeration development of living space in Suzhou became more obvious. The agglomeration effect of Zhangjiagang and Kunshan, as the sub-cores of development, weakened, and POI began to develop in a band-like pattern along the east-west direction, forming a distinct high-value area in the middle. In 2023, the living space in Suzhou City continued to expand. Distinct high-concentration zones were formed in densely populated areas (Figure 2). Throughout the city, there was a dense connection in a band-like pattern, and the trend of development axis formation became more pronounced. In the process of developing urban living space, internally, with Suzhou Industrial Park (SIP) as the core and the Yangtze River in the north and Taihu Lake in the south as the development axes, the development of urban living space in the north-south direction is achieved. Relying on the coordinated development of the Yangtze River Delta region and leveraging the geographical advantages of Shanghai and Zhejiang in the southeast, the rapid development of the sub-center of Kunshan City has been achieved. As a result, the number of interesting points in the eastern Kunshan and southern Wujiang regions has skyrocketed, and the number of high-value areas with high core density has significantly increased (Figure 2). From the perspective of distribution patterns, a multi-core living space pattern in Suzhou has gradually taken shape, with the central Industrial Park as the main core and Changshu, Zhangjiagang, Kunshan, and Wujiang as the sub-cores, achieving the development of POI density in Suzhou's living space from the center to the outside (Figure 2).

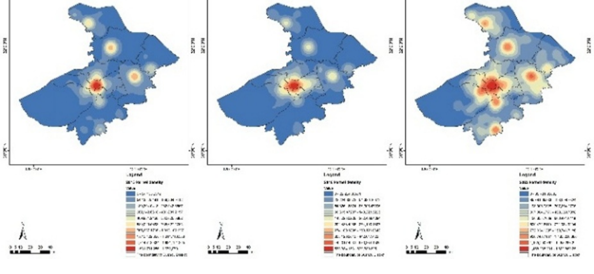

Figure 2. Analysis results of living space kernel density in different years.

3.1.2 Average Nearest Neighbor Index Analysis

During the period, the nearest neighbor ratio decreased from 0.1906 in 2013 to 0.1664 in 2018, indicating that the degree of aggregation of POI facility points increased. The nearest neighbor ratio decreased from 0.1664 in 2018 to 0.2727 in 2018, indicating that the degree of aggregation of POI facility points has weakened over time (Table 2). It can be judged that the spatial distribution of POIs related to the residents' lives in Suzhou first gathers in the center, and then continuously spreads from the center to the peripheral areas. However, the overall space shows significant agglomeration characteristics. By analyzing the nearest neighbor index of living Spaces in Suzhou City in 2013, 2018, and 2023, it is concluded that the living Spaces in Suzhou City all show a clustering trend. Among them, the nearest neighbor ratio values of the Sansheng space in 2023 were higher than those of each space in 2013 and 2018. The overall feature of POI in living Spaces is aggregation, and the development trend is to spread outward.

Table 2. Average nearest neighbor analysis results of Suzhou residents living in Spaces in 2013, 2018, and 2023.

Year	Average observation distance (m)	Expected average observation distance (m)	Nearest neighbor ratio	*Z* value	*P* value	Spatial agglomeration characteristics
2013	36.4436	191.1930	0.1906	-445.58	0	Clustered
2018	52.6082	316.1974	0.1664	-275.44	0	Clustered
2023	31.5246	115.6099	0.2727	-689.24	0	Clustered

3.2. Directional Feature Analysis

The standard deviation ellipse was calculated for the POI data in 2013, 2018, and 2023, respectively. From the elliptical distribution directions of the three years, it can be seen that they are all from northeast to southwest, which is consistent with the overall development status of Suzhou City (Figure 3).

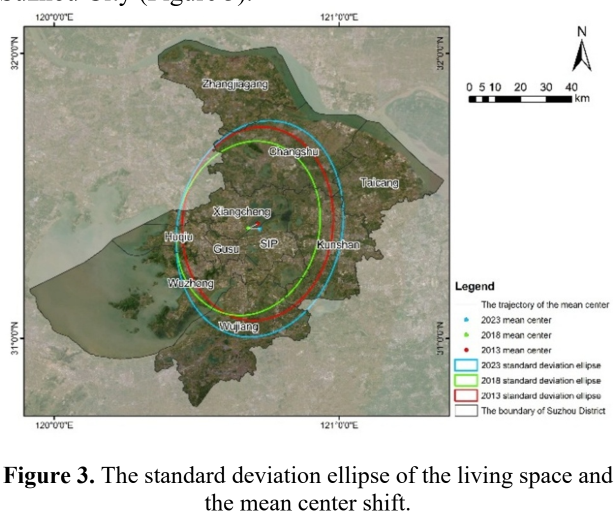

Figure 3. The standard deviation ellipse of the living space and the mean center shift.

From the generated area representing the range, it can be found that the living space range of Suzhou City in 2023 was larger than that in 2013. The aspect ratio of the ellipse generated in 2023 is lower than that of 2013, suggesting that the development of living space in 2023 has a more obvious direction than that in 2013. From the perspective of spatial rotation Angle changes, the rotation Angle has increased from 6.1512 in 2013 to 12.4741 in 2023 (Table 3), and the generated ellipse direction is consistent with the urban development direction of Suzhou City. In addition, the overall trend of the center of motion of the distribution pattern of residents' living Spaces in Suzhou City is first to move southwest and then southeast, from (120.7141 E, 31.4022 N) in 2013 to (120.7213 E, 31.3842 N) in 2023 (Table 3). The long half axis dropped from 0.3399 in 2013 to 0.3098 in 2018, then rose to 0.3831 in 2023 (Table 3). This indicates that the spatial distribution of economic development was first aggregated and then dispersed in the main directions, but the overall change was not significant.

Table 3. Standard deviation ellipse results of Suzhou residents living in Spaces in 2013, 2018, and 2023.

Year	Mean center longitude	Mean center latitude	X-axis length (m)	Y-axis length (m)	Rotation (°)
2013	120.7141	31.4022	0.2641	0.3399	6.1512
2018	120.6810	31.3865	0.2474	0.3098	15.4930
2023	120.7213	31.3842	0.2883	0.3831	12.4741

4. Conclusion

The functional classification of POI data constructed the residents' living space in Suzhou. Spatial analysis was conducted using GIS. Three time points, 2013, 2018, and 2023, were selected to study the evolution of the spatio-temporal pattern of the living space of residents in Suzhou, and the following conclusions were obtained:

(1) In 2013, 2018, and 2023, the interest points of residents' living Spaces in Suzhou City generally showed an agglomeration feature, but internally they showed a trend of diffusion and development.

(2) The overall distribution of living Spaces among residents in Suzhou City is oriented from northeast to southwest, and the development trend has not undergone significant changes from 2013 to 2023. According to the movement of Suzhou residents' living space development center, from 2013 to 2023, the center moved southwest and southeast. However, it was concentrated within the central urban area of Suzhou.

(3) Over the past decade, from 2013 to 2023, the living space for residents in Suzhou City has gradually developed into a "multi-core" pattern. The sub-core mainly develops in a strip-like pattern along the Yangtze River, and the city's sub-centers are concentrated in densely populated areas.

5. Discussion

Based on POI data, this study systematically analyzed the distribution characteristics of the living Spaces of residents in Suzhou City by comprehensively applying the kernel density estimation method, the standard deviation ellipse method, and the nearest neighbor index method. The research finds that the residents' living space in Suzhou City presents a "multi-core" spatial distribution pattern. There are significant differences in the distribution of living space among residents in different areas, and on the whole, it still expands outward.

This study breaks through the limitations of traditional statistical data and accurately identifies the spatial distribution patterns of residents' lives in Suzhou through POI. This technical approach can provide a replicable analytical framework for urban refined governance and facilitate planning transformation from "experience-driven" to "data-driven". However, this study also has certain limitations: the POI usage data only reflects the static distribution characteristics and fails to conduct an in-depth analysis of residents' actual usage frequency and satisfaction degree. Meanwhile, the acquisition of POI is based on map data. Some locations not listed on the map cannot be studied and analyzed, and thus cannot fully and accurately reflect the changing trends of the living Spaces of residents in Suzhou City.

Based on the research results and the territorial spatial planning of Suzhou City, the following suggestions are put forward to optimize the spatial structure. Given the significant disparity in the number of interest points in the living Spaces of residents in the northern (Xiangcheng) and southern (Wuzhong) parts of the central urban area of Suzhou (Xiangcheng and Wuzhong) compared to the rest of the central urban area, the uneven development levels among regions, the highly concentrated central core, and the relatively scattered peripheral distribution, the future planning and development of the region should focus on the balanced distribution of various functions. Strengthen the connections among various regions.

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