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Research Article

Dynamic Analysis of Multicenter Spatial Structure with Big Data in Smart City

Juan Liu

School of History and Public Administration, Yancheng Teachers University, Yancheng, 224000 Jiangsu, China

Correspondence should be addressed to Juan Liu; liuj01@yctu.edu.cn

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Based on dynamic big data, the multicenter spatial structure of cities is studied, which provides help for scientific planning of urban space and rational use of urban land. Firstly, the research background and significance of this topic is expounded in the Introduction, and then, the related concepts and theories, which lay a theoretical foundation for this research, are summarized. After that, the paper focuses on the design of the scheme of urban multicenter spatial structure and puts forward the method of multicenter identification, method of aggregation feature analysis, and method of spatial structure feature. Finally, the proposed scheme is verified by a case.

1. Introduction

Rapid urbanization and rapid population growth have led to rapid social and economic growth in developing countries and at the same time led to the expansion of urban space scale and the adjustment of urban internal structure. Multicore urban structure has increasingly become a trend, which alleviates various problems caused by the single-center urban structure, such as traffic congestion, excessive population density, environmental deterioration, and other typical "urban diseases." Multicore is an important concept in urban planning. This kind of "multicore" is formed by the rational spatial distribution of several core areas of different sizes in a city. The urban core area is an important component of urban spatial structure, which gathers the core service functions of a city and supports the development of urban economy, society, and culture. Therefore, it is of great significance to accurately identify the urban core region and analyze the multicore urban structure in space for urban planning and sustainable development.

Traditional research on urban spatial structure is mainly based on experience and investigation, which relies too much on subjective judgment. However, the study of the urban spatial structure by remote sensing data has the problems of complicated data processing, time-consuming, and labor-consuming. With the relative development of large-scale information technology and the rapid popularization of Internet applications, big data is rapidly entering people's life and production. Big data can supplement traditional spatial data in many ways and is gradually being used in the construction of smart cities and digital cities [1]. By describing the real geographical entities such as urban residence, commerce, transportation, and public resources, meanwhile crossing with other disciplines, we can study the behavior of microsubjects, which can strengthen the mastery of urban functions and provide angles and idea analysis for the study of urban problems. Big data technology has been widely used in urban research in recent years, providing important data support for the development of smart cities. POI is an important information contained in modern electronic maps, providing people with important spatial reference information, and its emergence has greatly promoted the application of spatial geographic information technology. As an important manifestation of spatial information, POI data can provide information about human activities in urban space. POI is widely used in urban research because of its advantages in urban spatial work orientation.

Therefore, the dynamic big data of the multicenter spatial structure of a smart city is analyzed based mainly on the multicenter theory.

2. Overview of Related Theories

2.1. Definition of Related Concepts

2.1.1. Urban Spatial Structure. Bourne (1952) gave an authoritative definition of urban spatial structure [2] on the basis of defining concepts of urban form and urban interaction. He believes that urban form is the spatial form and arrangement of individual urban elements (such as architecture, land use, social groups, economic activities, and public institutions) in urban areas. Urban interaction is a set of fundamental relationships, which integrate individual land use, types, and behaviors of group activities into a subsystem. The urban spatial structure connects the behavior and interaction between the urban form and subsystems through a set of organizational rules and connects these subsystems into an urban system [3]. This definition not only points out the constituent elements of urban spatial structure but also emphasizes the interaction network among the elements [4]. There are two main definitions of urban spatial structure in China: one is the start from the fact that urban economic activities are the basis of urban existence and development, which is considered that urban spatial structure is the embodiment of urban socioeconomic activities in urban areas. Besides economic activities, other functions of cities are also recognized in that urban spatial structure is the embodiment of various elements and functional organizations of cities in urban areas. Comparatively speaking, the second definition broadens the research object of urban spatial structure, which comprehensively reflects the characteristics of a city as a complex system.

2.1.2. Multiple Center. The meaning of multiple center is broader. By combing the previous studies, it can be seen that morphological polycentricity, functional polycentricity, and administrative polycentricity are all important branches of multicenter research in a broad sense. Urban form is the comprehensive result of the spatial distribution of elements within the city by following the analysis of the concept of "urban spatial structure." The multiple center discussed in this study is the concept of urban form, taking the basic definition of morphological polycentricity, which emphasizes the comprehensive distribution and morphological layout of static socioeconomic attributes within urban space [5].

At the same time, the multicenter spatial structure has dependence on spatial scale and certain fractal characteristics [6]; that is, there is self-similarity between different spatial scales [7]. From the national scale, the metropolitan area, city-region, continuous urban area, and urban agglomeration with relatively concentrated economic activities can be regarded as a single center. From the regional scale, the internal structure of these cities-region, urban sprawl, and urban agglomeration can be further deepened, or it will present a multicenter structure of administrative or functional regional scale with some cities or urban areas as the center. From the perspective of the city scale, the city which is the center in the previous scale will further explore its internal structure or will show the multicenter degree comprehensively reflected by units of small spatial scale [8]. This study focuses on the urban scale, and the object is the multicenter spatial structure within the megacities.

2.1.3. Big Data. Big data has become a popular word in today's society only a few years since its birth and development. Because it is an abstract concept, there is no clear definition of big data up to now. Figure 1 shows the characteristics of big data. At present, the comprehensive definition of big data is the "5V" feature put forward by IBM, which namely means volume, variety, velocity, value, and durability [9]. Volume refers to the large amount of collection, calculation, and storage of data; variety refers to the variety of types and sources of data; velocity refers to the high speed of data generation, collection, processing, and updating; value refers to the low value density of data, which seems to pan for gold in the sand; and veracity refers to the accuracy and authenticity of data, that is, the quality of data [10]. In urban planning, the value of big data is mainly reflected in the large scale and wide coverage of urban basic data. The application of big data is an innovation to the means of preparation in urban planning, and it expands the way for all sectors of society to participate in urban planning which transforms traditional static blueprint-describing planning into planning of optimization in a dynamic process [11].

2.2. Introduction of Related Theories.

Urban spatial structure involves multidisciplinary researches, including economics, geography, urban and rural planning, and others. There are differences in the focus of different disciplines, while the breakthrough and analysis perspective of research on urban spatial structure are also different [12]. "Space" is the basic concept and core element of geography, where the research on "urban spatial structure" in geography focuses on exploring the evolution law and analyzing the characteristics of spatial evolution and development patterns based on land use. The main research object of urban and rural planning emphasizes the research and design of urban space form, which discusses the law of combination and visual art principles among elements of material space. Economics highlights the formation mechanism, development, and evolution mechanism of urban spatial structure and focuses on the mechanism analysis behind the phenomenon. Since the new economic geography first integrated spatial factors into the process of economic construction and quantitative analysis, the role of spatial structure has been appreciated in the economic field [13]. Based on this, the theoretical analysis of the research on the spatial structure of multicenter cities will be made from the following three perspectives, specifically, including the perspective of planning, geography, and economics.

2.2.1. Planning Perspective: The Origin of Multicenter Concept. The concept of multicenter originates from the field of planning and belongs to the research scope of "urban form" which refers to the evolution of urban physical environment under the action of various activities within the city, including the structure of land use and functional layout within the city, as well as the external contour formed by the boundary in urban construction [14]. In the field of

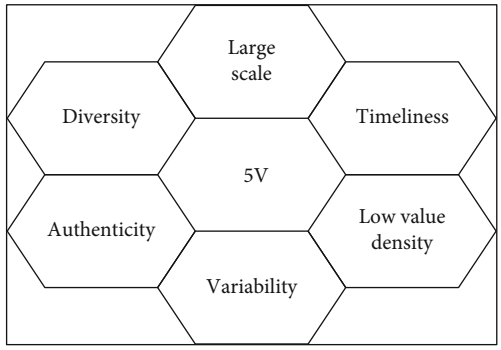

Figure 1: Characteristics of big data.

planning, the spatial structure of multicenter cities focuses on the evolution and development trend of the internal structure of cities, which is the spatial layout of various resources, and is also the result and comprehensive form of interaction of various activities in urban material space [15].

2.2.2. Geographical Perspective: Decentralization and Multiple Center of Element. In the traditional concept of urban geography, the regional shape of urban space is generally formed under the mutual influence of centrifugal force and centripetal force continuously emitted by the dominant "center of traditional city." After the 1920s, the phenomenon that the functions within the traditional city center gradually shift to the periphery of the city began to be recognized, which follows the concentric circle model, belt model, and multicore city model proposed by Burgess, Huo Yite, Harris, and others. Subsequently, the phenomenon of suburbanization of population was also reflected in some cities in the United States, and relevant theories surrounding the development trend of decentralization within the city continued to emerge at this stage. These theories focus on the emergence, evolution of suburban areas, feature induction, and relationship with traditional urban centers [16]. Then, in 1984, after the appearance of suburbanization in some metropolises in Britain and America, Peter Hall summed up a large number of urban phenomena and put forward the model of urban evolution which systematically depicts the evolution of urban internal structure [17]. According to this, the spatial process of the development of urban centers and suburbs can be understood under traditional urban geography theory as the process of agglomeration and dispersion of some urban functional areas that extends outward from the urban centers.

2.2.3. Economic Perspective: The Mechanism of Multicenter Formation and Evolution. The essence of economics is that it is dedicated to exploring the law of rational decision-making made by the subject through comprehensive cost-benefit to maximize utility [18]. Generally speaking, the theory of urban economics mainly focuses on the theory of land rent and agglomeration economy theory to analyze the formation and evolution of urban spatial structure, where the theory of land rent reveals the reasons and mechanisms of urban interior space and land layout from the perspective of individual residents, while the theory of agglomeration economy analyzes the reasons and rules of the comprehensive selection of location and the tendency of agglomerated distribution from the perspective of enterprises' pursuit of benefit maximization. By combining together the two above, they constitute the mechanism of the formation and evolution of urban internal spatial structure.

3. Analytics Scheme of Dynamic Data of Urban Multicenter Spatial Structure

For security reasons such as confidentiality, the original coordinates of the data needed for research belong to the Mars coordinate system, etc. Therefore, the coordinates of data should be corrected first, and then, the POI points, roads, urban boundaries, and other data should be projected to the coordinate system "WGS1984-UTM-Zone-51N" with the help of ArcGIS to establish a complete urban information database in geography for the next analysis.

3.1. Design of Multicenter Identification Scheme. The multicenter spatial structure of a city is a unique and complex spatial structure which gradually evolved under the joint action of natural conditions, historical development, planning guidance, and population migration, where the spatial distribution of city centers with different functions also has certain differences, as well as the distribution of different types of POI [19]. The amount of POI data varies greatly with different types. For example, there are 14,672 POI data for restaurants and only 857 POI data for business offices, while the same type of POI data also has different influences on the formation of urban centers that their influences on the formation of commercial centers are far less than those of shopping centers and shopping malls. To sum up, the specific design of multicenter identification based on POI data is shown in Figure 2.

The steps are as follows:

The first step is to classify urban facilities again according to different functions and carry out average nearest neighbor analysis. The results show that the nearest neighbor ratio (R) of all kinds of facilities is less than 1, which means that all facilities are clustered in space.

The second step is to study the distribution of various facilities by nuclear density analysis and normalize the results, which are divided into 1~10 grades.

The third step is to use the expert scoring method and use YAAHP software to calculate the influence weight of various facilities on different functional city centers.

The fourth step is to superimpose the normalized core density of the facility according to the weight which finally identifies the administrative center, business center, cultural and educational center, and leisure center of the city.

3.1.1. Analysis of Kernel Density Based on Average Nearest Neighbor Analysis. Average nearest neighbor analysis is used to calculate the distance between the POI point and its nearest neighbor POI point; then, the average value of all nearest neighbor distances is calculated. The final result will feed

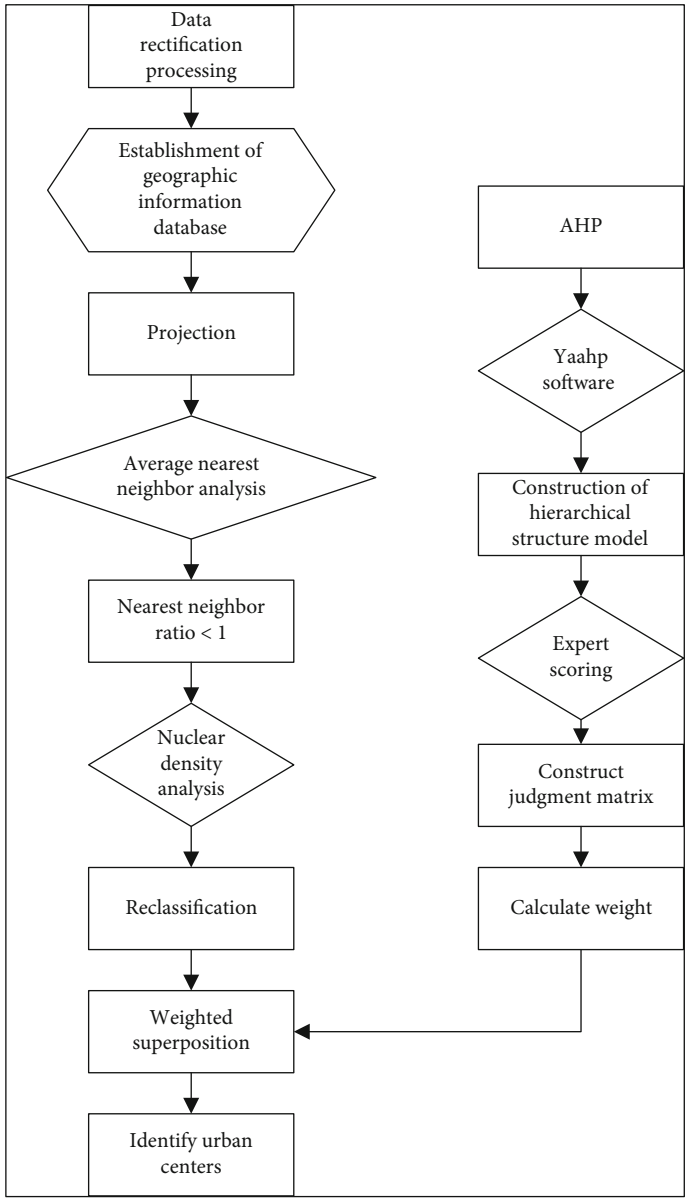

Figure 2: Design of identification in city center.

back five values, namely, average observation distance, expected average distance, nearest neighbor index, score of Z, and value of P. If the r is less than 1, the expression mode of this group is clustering, and the smaller the value, the higher the degree of clustering.

$$\bar{D}O = \frac{\sum_{i=1}^{n} d_i}{n},$$
$$\bar{D}E = \frac{0.5}{\sqrt{n/A}}, \quad (1)$$
$$R = \frac{\bar{D}0}{\bar{D}E}.$$

In the above formula, d_i refers to the distance between a certain point and its nearest neighbor, n is the total number of elements, and A refers to the minimum rectangular area around all elements or the value of the specified area.

Core density analysis means that any point is regarded as the core, and a certain range around it is the range of density calculation. According to the location of facilities, the spatial distribution form of this area is calculated and analyzed [20]. In this paper, nuclear density analysis is used to explore the gathering areas of various facilities in the East Coast City of Qingdao. Among them, the distance from the position of the core point determines the weight given to it, and the value of the final density is obtained from each data after weighted average analysis [21]. If the core density P_i of any point I in the space is defined as the core point with the highest weight, the value of the surrounding data points will decrease with the increase of distance, and when the

distance reaches the critical value r, the density value of the surrounding data points will be zero. The function expression is as follows:

$$P_i = \sum_{i=1}^{n} \frac{1}{\pi r^2} \varphi\left(\frac{d_{is}}{r}\right), \tag{2}$$

where P_i is the estimated value of nuclear density at i, r is the calculation radius of the function of kernel density, n is the total number of samples, d_{is} is the distance between the POI point i and s, and φ is the weight of the distance.

The purpose of the reclassification is to normalize the results of nuclear density with different particle sizes, which makes them in the grade of the same particle size that is convenient for the next calculation. For example, in the place of leisure and entertainment in the East Coast City of Qingdao, the range of nuclear density of picking gardens, resorts, and other facilities is 0~3.84, that of leisure places is 0~30.04, and that of entertainment facilities is 0~85.31. The numerical granularity of nuclear density of three types of facilities is quite different, and the results cannot be simply superimposed. Therefore, the reclassification in ArcGIS is used to reclassify the results into 1~10 grades for weighted calculation.

3.1.2. Weight Calculation Based on AHP. The Analytic Hierarchy Process (AHP) refers to the quantitative analysis method which decomposes the problems with strong subjectivity, many influencing factors, and difficulty in quantification to form a model of stepped hierarchical structure [22]. In the process of identifying the centers of different functions of cities, there are some differences in the influencing weights on the formation and distribution of urban centers, due to the different scales and quantities of facilities. Therefore, urban centers are firstly divided into four categories: administration centers, business office centers, culture and education centers, and leisure centers, and then quantitatively calculate the influence weights of various POI facilities on urban centers with the help of YAAHP [23]. The whole calculation is mainly divided into three steps: In the first step, according to the classification of POI facilities and the principle that the lower elements belong to the upper elements, the multilevel structure of the decision-making layer and middle layer is established. The second step is to build a matrix of pairwise comparison judgment between elements and divide the comparison of pairwise elements into five numerical grades of 9, 7, 5, 3, and 1 (respectively: absolutely important, very important, relatively important, slightly important, and equally important) and four levels between two adjacent levels, with values of 8, 6, 4, and 2. Meanwhile, experts in related fields are invited to judge the model of the hierarchical structure. The third step is to calculate the results and finally obtain the weights of various facilities [24]. Figure 3 shows the model of the multilevel structure of the leisure center.

3.2. Analysis Method of Aggregation Feature

3.2.1. Data Conversion and Analysis Ideas of Heat Map. In order to facilitate data analysis and calculation, different color areas are divided into seven grades of thermal values from 1 to 7 by means of classification and reclassification of a natural break point, among which grade 7 is the highest population density in this area [25]. For the convenience of description, the area with thermodynamic degree of 6~7 is defined as the high-heat area, and the area with thermodynamic degree of 4~5 is collectively referred to as the subheat area. The core idea of the analysis is to calculate the area of different thermal values, in which the larger the area of the high-heat zone and subheat zone, the higher the spatial concentration of people. Figure 4 shows the calculation ideas of the high-heat zone and subheat zone. Based on the conventional understanding of the law of urban activity and the demonstration of existing research, the law of activities is influenced by work factors to a great extent, showing periodic changes on a weekly basis, and there is a certain difference between the law of population distribution of working days from Monday to Friday and rest days on Saturday and Sunday [26]. Therefore, in this paper, the thermodynamic values displayed by Baidu heat maps on working days and rest days are investigated. After the study of the distribution and area of the high-heat zone and subheat zone, the location of the urban population center of gravity in different periods and the law of track of the population center of gravity in urban space are calculated by the "Spatial Statistics Tools-measuring geographical distribution-average center" system.

3.2.2. Analysis of Aggregation Based on Classification Method of Natural Discontinuities. The classification method of natural discontinuities is that the category of "natural discontinuities" is based on the natural grouping in the data. The similar values can be grouped appropriately by identifying the classification interval, while the differences between classes is maximized, as shown in Figure 5. Also, the features will be divided into several categories, and for these categories, the boundaries will be set at the positions where the values are relatively different [27]. Therefore, the classification of all data in this paper adopts this method, so as to ensure that the characteristics of the data can be more clearly and intuitively displayed after classification. The formula is as follows:

$$X = \frac{\sum_i^n \times W_i X_i}{\sum_{i=1}^n W_i},$$
$$Y = \frac{\sum_i^n \times W_i Y_i}{\sum_{i=1}^n W_i}. \tag{3}$$

In the formula above, x and y, respectively, represent the coordinates of latitude and longitude of the center of gravity of population distribution, W_i represents the thermal value of the i-th element, X_i and Y_i represent the coordinates of the i-th element, and n is the total number of elements in the region.

3.3. Analysis Method of Characteristics in Spatial Structure. In order to analyze accurately whether there is a spatial coincidence relationship between each functional center and

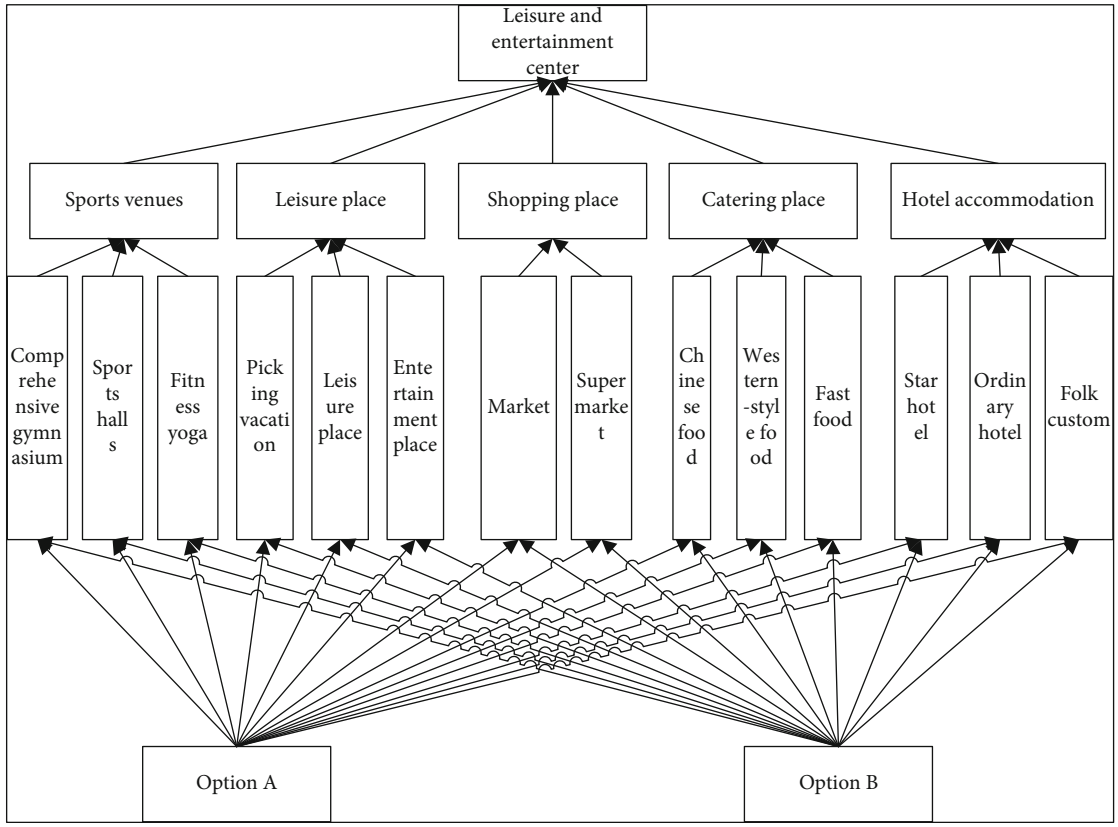

Figure 3: Model of multilevel structure of leisure center.

population gathering area, this paper adopts the visualization method of two-factor superposition mapping. The principle of two-factor superposition mapping is to combine two groups of different data into four different results according to their numerical values, which can form a transition zone between these combinations and combine them into more combinations [28]. However, this paper is only to study whether there is a relationship of spatial coincidence between the functional centers of cities and the gathering areas of population. Therefore, only the 3×3 classification method is adopted, and finally, nine different factors are combined. In order to more intuitively analyze and express the spatial coupling relationship between POI data and thermal value data, POI data was assigned 0, 5, and 9 according to its conditional function, while thermal value data was assigned 3, 1, and 0. Figure 6 shows the process of mapping in two-factor superposition.

As the principle of heat map in Baidu is also a kind of analysis of kernel density based on the user's location in the Baidu map APP which belongs to a kind of raster data, as shown in Figure 7, it is possible to extract the high-density (Grade 9 and Grade 10) and medium-density (Grade 7 and Grade 8) areas in a map of POI kernel density and assign 1, 3, 5, and 9 to the high-heat area and subheat area in the heat map, respectively, while the low-density area (Grades 1–6) and low-heat area are assigned to 0 and combined in pairs to obtain 9 types of combination relationships and color matching (which is shown in Figures 3–6 for details). According to the superposition and spatial distribution of different relationship types, this paper discusses the spatial coupling relationship between POI data and the heat map in Baidu and further analyzes the relationship between its spatial differences and the multicenter spatial structure of Qingdao.

4. Analysis of Case

4.1. Overview of the Research Area. Qingdao is located in the south of Shandong Peninsula, at 119°30′~121°00′ east longitude and 35°35′~37°09′ north latitude. In the master urban plan of Qingdao (2010-2020), the coastal area around Jiaozhou Bay is called the central urban area, including Shinan District, Shibei District, Licang District, and Laoshan District on the east bank of Jiaozhou Bay, Chengyang District and Hongdao Economic Zone on the north bank, and Qingdao Economic and Technological Development Zone on the west bank. The area studied in this paper is the eastern urban area under the urban space expansion strategy of "Linkage of the Three Cities."

The research area selected in this paper is the city in the east coast of Qingdao, which covers an area of 592.95 square kilometers with a permanent residence of 2,678,400 that accounts for 28.83% of the city's permanent residents. Table 1 shows the information on the subdistrict area, population, and economy. The city in the East Coast of Qingdao is the key area of transformation and development of urban space, which is a comprehensive service center with administration, culture, finance, business, and tourism.

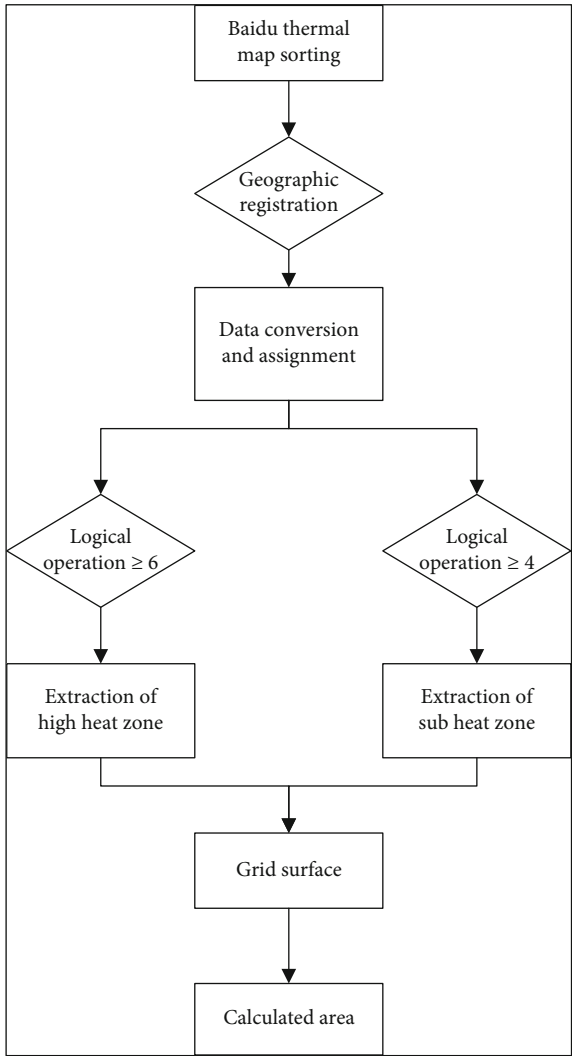

Figure 4: Process of calculating the area of heat diagram.

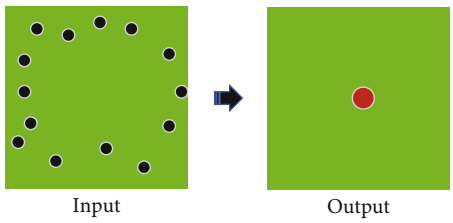

Figure 5: Schematic diagram of average center.

4.2. Results of Multicenter Identification

4.2.1. Administrative Center. POI interest of administrative facilities mainly include administrative units at or above the municipal level, district/county level, and township level and below; departments of public security and inspection; agencies of traffic and vehicle management; industrial and commercial tax authorities; and various social organizations. A total of 3565 pieces of data are obtained after deduplication. On the basis of summarizing the results of existing research, the administrative facilities are reclassified according to the level and function of the facilities.

4.2.2. Business Office Center. The main body of facilities in business office studied in this paper not only includes facilities such as finance, insurance, law, advertising, information, and technical services but also includes management and service departments of various industries. Therefore, the facilities are divided into banks, insurance institutions, securities companies, office buildings, commercial and residential buildings, companies, and hotels, which are a total of 19,714. Among them, the number of companies is the largest, with a total of 14,927, which accounts for about three quarters of the total facilities. Financial facilities, including all kinds of banks and their branches (excluding ATM facilities), insurance companies, investment companies, and securities companies, are 1906 in total. Office buildings include 857 commercial buildings and commercial and residential buildings which are the core element of forming a business office center, as shown in Table 2.

4.2.3. Cultural and Educational Center. In this paper, it is simply divided into a book exhibition category, including libraries, archives, museums, and art galleries, as shown in Table 3, totaling 201 according to the POI, and news media, including newspapers, magazines, advertising media, and other facilities, a total of 217. The number of training facilities is the largest, including primary and secondary schools and other basic educational facilities, colleges, and universities and various training and counseling institutions, which total 7747.

4.2.4. Leisure Center. As shown in Table 4, there are a large number of leisure facilities, up to 25,301, which are mainly divided into sports venues, including comprehensive gymnasiums and gymnasiums; leisure places, including picking gardens, resorts, chess and card rooms, and KTV; shopping places, including large shopping malls, shopping centers, supermarket chains, and convenience stores; catering services, including Chinese restaurants, western restaurants, and fast-food restaurants, which account for the largest proportion among leisure and entertainment facilities; and hotel accommodation facilities, mainly including star-rated hotels, ordinary hotels and homestays, and partying halls.

4.3. Results of Aggregation. Table 5 shows the results of multicenter aggregation.

4.4. Analysis of Spatial Structure Characteristics. The mixed function multicenter is the embodiment of the multicenter structure of urban cluster, which is more appropriate to the connotation of the multicenter space structure inside the city. The eastern urban area is the central urban area showing the characteristic cultural deposits of Qingdao and is the key area of urban space transformation and development. It should focus on improving the living environment, solving urban problems, and taking the road of connotative development. Under the guidance of the intervention of the master plan, urban elements continue to gather in specific areas and produce a city subcenter with comprehensive

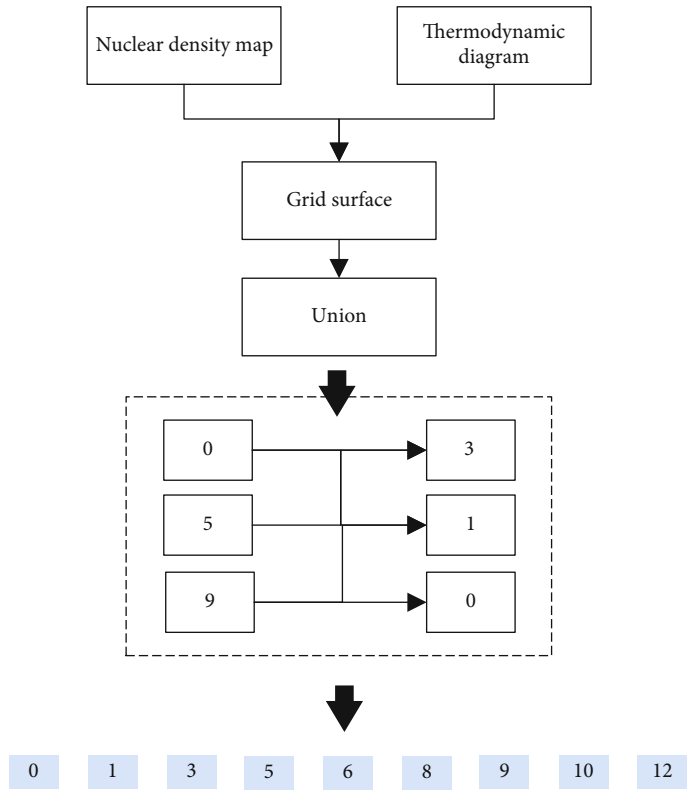

Figure 6: Process of mapping in two-factor superposition.

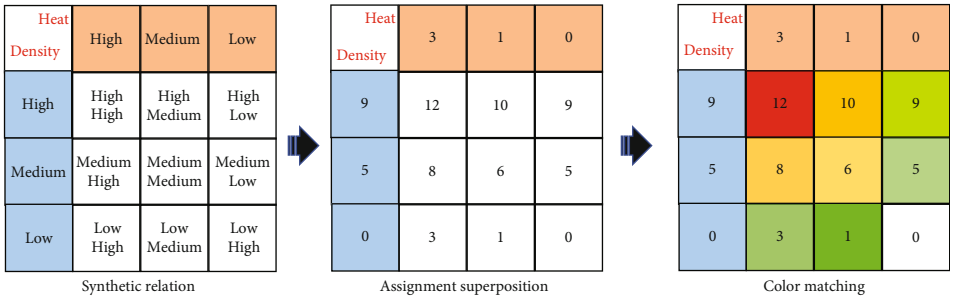

Figure 7: Method of mapping in two-factor superposition.

Table 1: Data and classification of administrative facilities.

General category	Medium class	Subclass	Quantity (PCs)	Proportion (%)	Nearest neighbor ratio (R)	Weight
Administrative center	Administrative units at or below the county and township levels	District and county administrative units	238	6.68%	0.43	0.165
		Township administrative unit	343	9.62%	0.17	0.043
		Below township level	800	22.44%	0.24	0.019
	Government office	Above prefecture-level city	361	10.13%	0.31	0.500
		Public security, procuratorial, and judicial departments	680	19.07%	0.34	0.168
	Social groups	Social groups	1143	32.06%	0.39	0.100
Total			3565	100%		

Table 2: Data and classification of business centers.

General category	Medium class	Subclass	Quantity (PCs)	Proportion (%)	Nearest neighbor ratio (R)	Weight
Business office center	Balance insurance	Bank	773	3.92%	0.31	0.045
		Insurance institutions	1026	5.20%	0.30	0.072
		Securities company	107	0.54%	0.60	0.171
	Office building	Office building	487	2.47%	0.49	0.377
		Apartment building	370	1.88%	0.59	0.126
	Company	Company enterprise	14,927	75.72%	0.29	0.158
		Hotel	216	1.10%	0.48	0.038
		Guesthouse	1808	9.17%	0.37	0.013
Total			19,714			

Table 3: Data and classification of cultural and educational facilities.

General category	Medium class	Subclass	Quantity (PCs)	Proportion (%)	Nearest neighbor ratio (R)	Weight
Culture and education center	Book exhibition	Library and archives	52	0.57%	0.66	0.182
		Art exhibition	109	1.19%	0.53	0.363
		Bookstore book bar	40	0.44%	0.62	0.031
	News media	Newspapers and magazines	78	0.85%	0.85	0.093
		Media organization	139	1.52%	1.52	0.024
	Education and training	Elementary education	1082	11.80%	11.80	0.102
		Colleges and universities	226	2.47%	2.47	0.129
		Training institutions	6439	70.23%	70.23	0.056
	Famous scenery	Famous scenery	824	8.99%	8.99	0.070
	Cultural activities	Cultural activity center	179	1.95%	1.95	0.051
Total			9168	100%		1

Table 4: Date and classification of leisure centers.

General category	Medium class	Subclass	Quantity (PCs)	Proportion (%)	Nearest neighbor ratio (R)	Weight
Leisure and entertainment center	Sports venues	Comprehensive gymnasium	27	0.11%	0.70	0.181
		Sports halls	372	1.47%	0.50	0.060
		Yoga gym	1188	4.69%	0.42	0.027
	Leisure place	Picking resort	73	0.29%	0.74	0.066
		Leisure entertainment	416	1.64%	0.46	0.030
		Entertainment place	1252	4.95%	0.31	0.041
	Shopping place	Market	140	0.55%	0.52	0.068
		Supermarket	878	3.47%	0.45	0.024
	Food and beverages	Chinese food	11,887	46.97%	0.21	0.014
		Western-style food	615	2.43%	0.34	0.039
		Fast food	2170	8.57%	0.29	0.015
	Hotel accommodation	Star hotel	216	0.85%	0.47	0.018
		Ordinary accommodation	1808	7.14%	0.36	0.010
		Homestay	4259	16.83%	0.27	0.047
Total			25,301			

Table 5: Results of multicenter aggregation.

	Nearest neighbor ratio	Aggregation characteristics
Administrative center	The nearest neighbor ratio of administrative POI points is less than 1, which passes the test at the significance level of 0.01.	It shows that the spatial distribution of such facilities has significant agglomeration characteristics, in which the index of township level administrative and public institutions is the lowest ($r = 0.17 < 1$, $z = -29.38$); that is, the aggregation degree of such facilities is the highest, and the nearest neighbor index of district- and county-level administrative units is the highest ($r = 0.43 < 1$, $z = -16.87$), indicating that the aggregation degree is the lowest.
Business office center	The nearest neighbor ratio of business office POI points is less than 1, which passes the test at the significance level of 0.01.	It shows that the distribution of business office facilities in the urban area presents a cluster model. However, the nearest neighbor ratio of securities companies ($r = 0.60 < 1$, $z = -7.83$) and apartment buildings ($r = 0.59 < 1$, $z = -15.10$) is the highest, indicating that the aggregation degree of the two types of facilities is relatively low. The number of corporate facilities is not only large, but also, the nearest neighbor ratio is the lowest ($r = 0.29 < 1$, $z = -166.67$), indicating that the aggregation degree of corporate office facilities is the highest.
Culture and education center	The nearest neighbor ratios of cultural and educational POI points are less than 1, which pass the test at the significance level of 0.01.	The distribution of cultural and educational facilities in the urban area presents a cluster model. Among them, the nearest neighbor ratio of training institutions ($r = 0.25 < 1$, $z = -114.41$) is the lowest, which means that the aggregation degree of such facilities is higher than that of other cultural and educational facilities. Book exhibition hall ($r = 0.66 < 1$, $z = -4.75$), art exhibition ($r = 0.53 < 1$, $z = -11.04$), newspapers and magazines ($r = 0.62 < 1$, $z = -6.48$), and media institutions ($r = 0.60 < 1$, $z = -8.94$) have a high nearest neighbor ratio, indicating that the spatial aggregation degree of these facilities in the urban area is relatively low [29].
Leisure and entertainment center	The nearest neighbor ratio of leisure and entertainment POI points is less than 1, which passes the test at the significance level of 0.01.	It shows that the distribution of such facilities in the urban area presents a cluster model. Among them, the comprehensive gymnasium ($r = 0.7 < 1$, $z = -3.01$) and picking resort garden ($r = 0.74 < 1$, $z = -4.20$) have the lowest degree of aggregation due to their large scale and small number. Chinese restaurant ($r = 0.27 < 1$, $z = -164.53$), homestay ($r = 0.27 < 1$, $z = -91.56$), and other catering and accommodation facilities have the largest number, and the nearest neighbor ratio is relatively low, indicating that their aggregation characteristics in the urban area are significant compared with those in the urban area.

functions. If an area has two or more functions at the same time, it is called an urban center.

At present, the Qingdao east bank urban area has formed a total of 6 urban centers; the aggregation of various facilities in the east coast of Qingdao presents a spatial structure of "one main center, two subcenters, and three groups" and shows a strong main center, weak subcenter, and multilevel multicenter spatial pattern. The main center is the central district of Hong Kong Middle Road, which is the largest multifunctional urban center with the city government as the core and a radius of 2 km, where the main administrative, commercial, commercial, entertainment, and other functions of Qingdao are gathered. The two subcenters are the Zhongshan Road Historic Block and Taitung Dengzhou Road Block. The former is the origin of Qingdao's urban development and used to be the city center. The latter is a traditional commercial center rising rapidly with the relocation of industrial facilities, located between the old and new city centers. The three groups are Fuxin Road street, Li Cun street, and Jinjialing street along the Haier Road; in addition to the Fuxin Road street, the other two groups are far from the main center of the city. As a whole, the distribution of urban centers in the eastern urban area of Qingdao is not balanced. Most of the urban centers are located in the southern coastal areas. In the inland area, only a multicenter cluster is formed in Licun, while other inland areas are not multicenters with comprehensive functions.

5. Conclusion

To sum up, the multicenter theory, based on the POI of Gaode map and data of heat map in Baidu, is combined in this paper, and the scheme of a dynamic data based on the urban multicenter spatial structure is designed, in which the analysis method of the average nearest neighbor is used to classify urban multiple centers, and the analytic hierarchy process is used to calculate the weights. Classification intervals are identified by means of classification

and reclassification of the natural break point, so as to ensure that the data can present its characteristics more clearly and intuitively. Finally, the city in the east coast of Qingdao is taken as a case, which refers to the above scheme. The case shows that the center of the city in the east coast of Qingdao is divided into an administrative center, business office center, cultural and educational center, and leisure center. At present, the Qingdao east bank urban area has formed a total of 6 urban centers, which are "one main center, two subcenters, and three groups," and shows a strong main center, weak subcenter, and multilevel multicenter spatial pattern.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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