Sensors and Materials, Vol. 34, No. 12 (2022) 4355–4368
MYU Tokyo

S & M 3115

Evolutionary Characteristics of Spatiotemporal Distribution of Tourists in Hangzhou and Its Influencing Factors

Yue Wang, Qiuju Wang,* Zhaoyun Zhong, and Xiaorui Zhang

Tourism College of Beijing Union University, Beijing 100101, China

(Received September 20, 2022; accepted November 14, 2022)

Keywords: spatiotemporal evolution, GeoDetector, passenger flow analysis sensor, tourist volume

With the advent of the mass tourism era and the rapid development of all-for-one tourism, the spatiotemporal distribution of tourists has undergone major changes, resulting in significant challenges to the carrying capacity of tourist destinations and the spatial structure and organization of the tourism industry. On the basis of the tourist volume data of Hangzhou obtained from passenger flow analysis sensors and *Hangzhou Tourism Overview*, in this paper, we visualize the spatiotemporal distribution of tourists in the past ten years and explore its evolutionary law through the research methods of kernel density analysis, standard deviation ellipses, and gray system prediction. Six factors affecting the tourist volume, namely, the number of service providers, tourism demand scale, economic development level, policy support, tourist reception capacity, and tourism resource endowment, were also probed using the GeoDetector statistical method. We found that the distribution of tourist density in Hangzhou has changed from one core to multiple cores and the overall spatial agglomeration has decreased. The trend of tourists moving westward is expected to continue. Among the factors behind this change, the number of service providers has the highest effect and the tourism resource endowment has the lowest effect. The interaction of various factors can promote the evolution of the spatiotemporal distribution of tourists.

1. Introduction

With the advent of the mass tourism era and the rapid development of all-for-one tourism, the spatiotemporal distribution of tourists has undergone major changes, resulting in significant challenges to the carrying capacity of tourist destinations and the spatial structure and organization of the tourism industry. The 14th Five-Year Plan for Tourism Development emphasizes the importance of optimizing the spatial layout of tourism. It clearly points out how to allocate tourism resources reasonably, focus on solving the problem of the uneven spatial distribution of tourism development, and build a tourism support system to promote high-quality development. In the new development environment, urgent questions in tourism research include the following: What kind of changes have occurred in the spatial and temporal distributions of tourists? What are the factors behind the changes?

*Corresponding author: e-mail: wqiuju@126.com
https://doi.org/10.18494/SAM4126

ISSN 0914-4935 © MYU K.K.
https://myukk.org/

Tourist volume is an important indicator for studying the spatiotemporal distribution of tourists. This indicator shows the difference in the attractiveness of various areas as tourist destinations in the spatial dimension and reflects the changes in tourist destination hotspots in the temporal dimension.(1) Many studies have been conducted on the spatiotemporal evolutionary characteristics of tourists. From a temporal perspective, they have mostly focused on seasonal changes in tourist distribution(2,3) and the life cycle theory of tourist destinations.(4) For example, the travel blogs of Chinese tourists in northern Europe have been used to analyze the behavior of tourists from a seasonal perspective(5) as well as to determine the type of tourism by combining the spatial and socioeconomic dimensions of seasonality.(6) From a spatial perspective, studies have focused on the spatial characteristics of tourist distributions, mostly in close combination with web attention(7) and web searches.(8) Although there have been many studies on the spatiotemporal distribution of tourists, most of them were large-scale studies from an interprovincial perspective and small-scale studies of single tourist destinations or popular tourist regions. There have been few studies analyzing the evolutionary characteristics of the spatiotemporal distribution of tourists at the city scale. In addition, considerable research has been carried out on the factors affecting the spatiotemporal distribution of tourists. However, most of research studies explored how individual factors such as climate(9) and traffic(10) affect changes in tourist volume, and comprehensive and systematic analyses are lacking. Studies exploring the combined effects among the influencing factors are not yet common.

With the improvement of sensing systems, diverse sensing technologies are meeting the needs of different fields. A new monitoring system for tourist attractions based on RFID technology and a sensor system has achieved a comprehensive upgrade of functionality and stability, strengthening the management efficiency of the existing monitoring system.(11) Passenger flow analysis sensors are now a common infrastructure at tourist attractions for obtaining real-time spatial and temporal visitor location information based on a scenic flow control system, providing scientific guidance for operations, planning, and decision making.

Hangzhou is one of the first national historical and cultural cities in China and also a national key scenic tourist city. It has been identified as the best tourist destination city by the Ministry of Culture and Tourism. As a model city for all-for-one tourism, Hangzhou has complete tourism facilities and diversified products. Under the guidance of the strategy "city expansion to the east, tourism to the west", Hangzhou has formed a new tourism pattern. As a well-known tourist city, Hangzhou attaches great importance to monitoring the distribution of tourists, and intelligent passenger flow analysis sensors have been installed in many key scenic spots. These sensors provide basic support for studying the evolution of the spatiotemporal distribution of tourists at the city scale and the influencing factors.

Taking Hangzhou as an example, in this paper, we analyze the kernel density characteristics and standard deviation ellipses of tourists in the past ten years to explore the patterns of evolution of the tourist spatiotemporal distribution. In addition, the GM(1,1) gray system prediction method is used to forecast the evolution trend with the aim of improving the tourism development environment in the region and developing high-quality tourist destinations. We also use the GeoDetector statistical tool to detect six factors affecting the tourist volume to clarify the characteristics and changing trends of the spatiotemporal distribution of tourists.

2. Methods

2.1 Kernel density analysis

In this paper, kernel density analysis is adopted to elucidate the spatiotemporal distribution characteristics of tourists in Hangzhou, where a higher kernel density indicates a higher tourist density. Kernel density analysis is a classical spatial analysis method to infer the overall distribution density by calculating the density of elements in the surrounding neighborhood. This method takes the location of tourists as the origin; the closer to the origin, the greater the weight assigned and the greater the value of the kernel function, with the maximum value obtained at the origin.(12) This operation is repeated for all data points in the desired region, and the density at each location is superimposed to finally obtain the kernel density of tourists in the whole region. Assuming that x_1, $x_2 \ldots x_n$ are independently identically distributed samples drawn from an overall population with the standard normal distribution, the estimate at x_0 is

$$\hat{f}\left(x_0\right) = \frac{1}{nh}\sum_{i=1}^{n}\boldsymbol{K}\left(\frac{x_i - x_0}{h}\right), \tag{1}$$

where $\boldsymbol{K}\left(\frac{x_i - x_0}{h}\right)$ is the kernel function, $h > 0$ is the band width, $x_i - x_0$ is the distance from the valuation point x_i to x_0, and n is the number of study objects.

2.2 Standard deviation ellipse

We use the standard deviation ellipse method to show the spatiotemporal variation characteristics of tourists in Hangzhou. This method takes the center of gravity, x-axis length, y-axis length, and azimuth angle as the basic parameters, which can quantitatively explain the characteristics of centrality, spread, direction, and spatial pattern of the spatial distribution of geographical elements from a spatial perspective.(13) The quantitative description of the characteristics of a standard deviation ellipse can clearly show the degree of agglomeration, relative position, and the main trend of tourists(14) to illustrate the variability of the spatial distribution of tourists between different years. The coordinates of the center of gravity of the ellipse represent the highest concentration of Hangzhou tourists on the map space, the long axis is the direction with the lowest spatial distribution of tourists, and the short half-axis indicates the range. The equations for the center of gravity, rotation angle, and the standard deviation of the x- and y-axes of the ellipse are as follows:

$$SDE(x,y) = \left(\sqrt{\frac{\sum_{i=1}^{n}\left(x_i - X\right)^2}{n}}, \sqrt{\frac{\sum_{i=1}^{n}\left(y_i - Y\right)^2}{n}}\right), \tag{2}$$

$$\tan\theta = \frac{\left(\sum_{i=1}^{n}\overline{x}_i^2 - \sum_{i=1}^{n}\overline{y}_i^2\right) + \sqrt{\left(\sum_{i=1}^{n}\overline{x}_i^2 - \sum_{i=1}^{n}\overline{y}_i^2\right)^2 + 4\left(\sum_{i=1}^{n}\overline{x}_i\overline{y}_i\right)^2}}{2\sum_{i=1}^{n}\overline{x}_i\overline{y}_i}, \tag{3}$$

$$\sigma_x = \sqrt{\frac{4\sum_{i=1}^{n}\left(\overline{x}_i\cos\theta - \overline{y}_i\sin\theta\right)^2}{n}};\ \sigma_y = \sqrt{\frac{4\sum_{i=1}^{n}\left(\overline{x}_i\sin\theta - \overline{y}_i\cos\theta\right)^2}{n}}, \tag{4}$$

where x_i and y_i are the spatial coordinates of each element, x and y are the arithmetic mean centers, $\overline{x}$ and $\overline{y}$ are the differences between the mean centers and the x- and y-coordinates, respectively, and n is the total number of samples.

2.3 GeoDetector

GeoDetector is a statistical method that can be used to explain the driving force behind the spatial heterogeneity of geographic elements, which is beneficial when analyzing the spatial heterogeneity of research objects and measuring the explanatory strength of research variables for overall properties. GeoDetector can identify whether the joint action of independent variables changes the explanatory strength of the dependent variable compared with the original variables themselves, i.e., whether there is an interaction between different variables. This can effectively break through the limitations of traditional statistical methods on assumptions and provide new ideas for exploring the factors affecting research elements. The method is based on the basic assumption that independent and dependent variables have similar spatial distributions when the independent variable has a significant effect on the dependent variable.[15] A spatial relationship can effectively overcome the limitations of a traditional linear relationship. GeoDetector can measure the strength of the effect of the independent variable x on the spatial divergence of the dependent variable y to explain the true strength of the association between the two variables. This strength is measured from the q-value, where the larger the q-value, the more strongly the corresponding independent variable x explains the dependent variable y. The q-value is expressed as

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2}, \tag{5}$$

where L is the variable classification and h is the number of layers. Moreover, N and N_h are the numbers of intralayer and intrazone cells, and σ_h^2 and σ are the intralayer and region-wide variances, respectively.

3. Characteristics and Trend Forecast

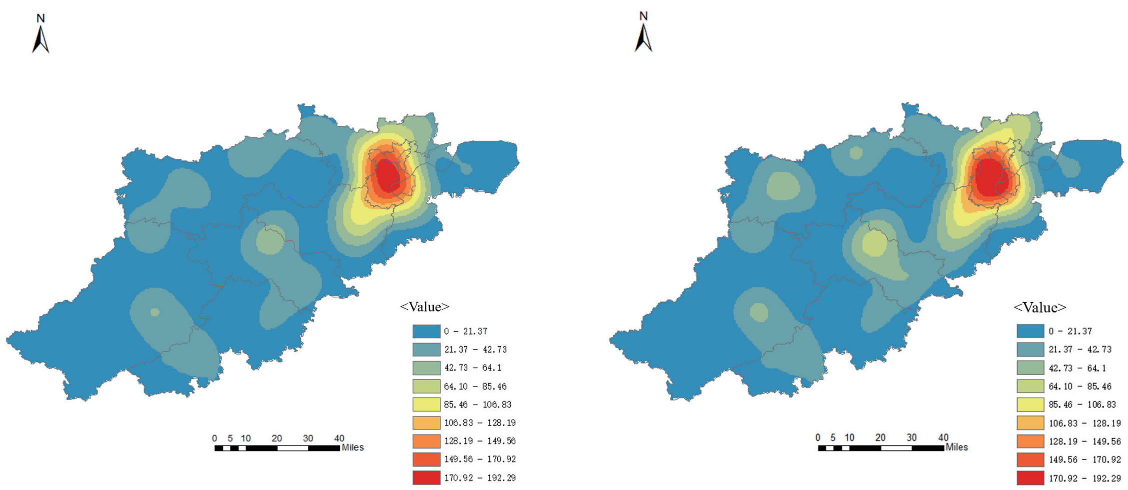
3.1 Data sources

We selected 105 famous tourist attractions in Hangzhou as the research object, including three 5A tourist attractions, namely, West Lake Scenic Area, Thousand Island Lake Scenic Area, and Xixi National Wetland Park; 42 4A tourist attractions, such as Yuhang Liangzhu Museum, Qinghefang Historic Block, Leifeng Tower Scenic Area, and Xianghu Scenic Area; and 57 3A tourist attractions, such as Lin'an Cloud Manufacturing Town, Lingshan Town, Red Tea Mountain Scenic Area, and Wenwu Shangtian Village. The tourist volume data of each scenic spot are from *Hangzhou Tourism Overview* from 2013 to 2020. However, since the data of some attractions are incomplete, they are supplemented by the results obtained with passenger flow analysis sensors. It was verified that the data obtained with the sensors differed little from the conventional statistics.

Owing to the limited statistics of tourism data, to better reflect the overall distribution pattern of tourists in Hangzhou, it is necessary to make tourists more evenly distributed in space. For this purpose, we used ArcGIS 10.4 software to geospatially visualize 105 A-class attractions with the center of each attraction given representative coordinates, and we generated Tyson polygons to divide the neighboring areas of each attraction using these coordinates to obtain geospatial boundary data for tourist attractions.[16] The tourist volume of each attraction was divided by its corresponding Tyson polygon area for densification. Finally, we obtained the kernel density map of the tourist distribution in Hangzhou from 2013 to 2020 (Fig. 1).

3.2 Evolutionary characteristics of spatiotemporal distribution

Through the kernel density maps of the tourist distribution in the past ten years, we found that the spatial distribution of tourists in Hangzhou has developed from one core to multiple



(a) (b)

Fig. 1. (Color online) Kernel density map of tourist distribution in Hangzhou from 2013 to 2020. (a) 2013. (b) 2014.

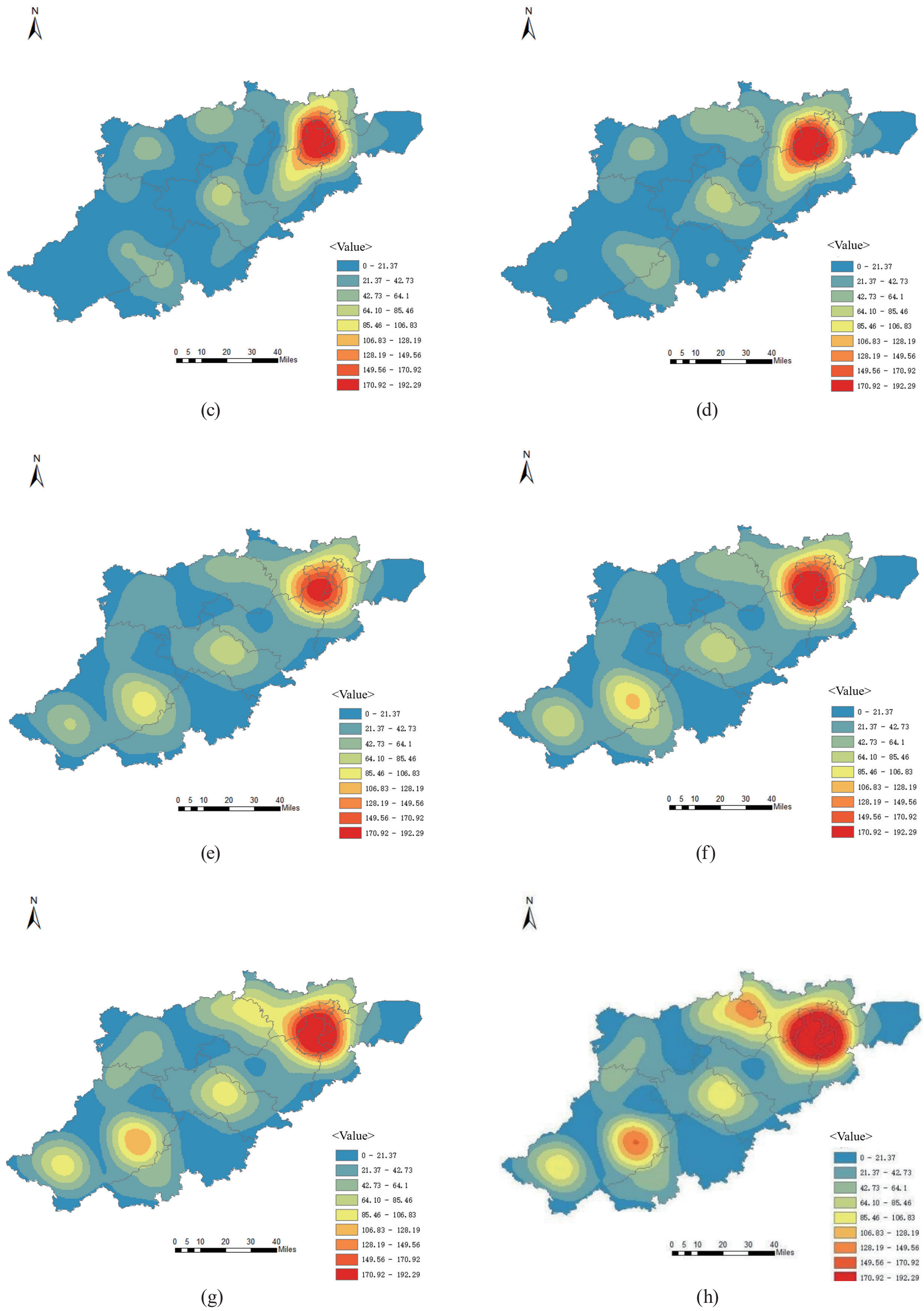


Fig. 1. (Continued) (Color online) Kernel density map of tourist distribution in Hangzhou from 2013 to 2020. (c) 2015. (d) 2016. (e) 2017. (f) 2018. (g) 2019. (h) 2020.

cores. In 2013, with the West Lake Scenic Area as the center, the area surrounded by the Leifeng Pagoda Scenic Area, Songcheng Tourist Scenic Area, Xixi National Wetland Park, and Beijing-Hangzhou Grand Canal Hangzhou Scenic Area as the core boundary formed a single-core tourist area concentrated in the northeast main city. From 2014 to 2016, there was a tendency for tourists to move westward. A second core area, represented by Yaolin Paradise Scenic Area, Langshi Golden Beach Scenic Area, and Chuiyun Tongtian River Scenic Area, and a third core area along Qiandao Lake gradually formed in Tonglu County. From 2017 to 2019, the distribution characteristics of the existing tourist cores further strengthened, and the high-density range around the core point expanded. By 2020, a pattern of five peak density areas, namely, the main urban area, northeastern Yuhang District, northern Tonglu County, the main shore of Qiandao Lake Reservoir, and southwestern Qiandao Lake, had been established.

From Fig. 2 and Table 1, it can be seen that the ellipse of standard deviation of tourists in Hangzhou has been relocated in two rough stages. The first stage was from 2013 to 2016, when the center of gravity point moved continuously southwest from (120.037°E, 30.187°N) to (120.013°E, 30.167°N). There is no large displacement of the center of gravity position as a whole, and the two axes were slightly changed in length. In the second stage, from 2017 to 2020, the center of gravity continued to moved southwest from (119.967°E, 30.139°N) to (119.952°E, 30.129°N), although it moved back to the northeast in 2018. The difference between the long and short semi-axes increased in the second stage, and the area of the standard deviation ellipse increased, indicating that the tourist distribution had become more spatially divergent.

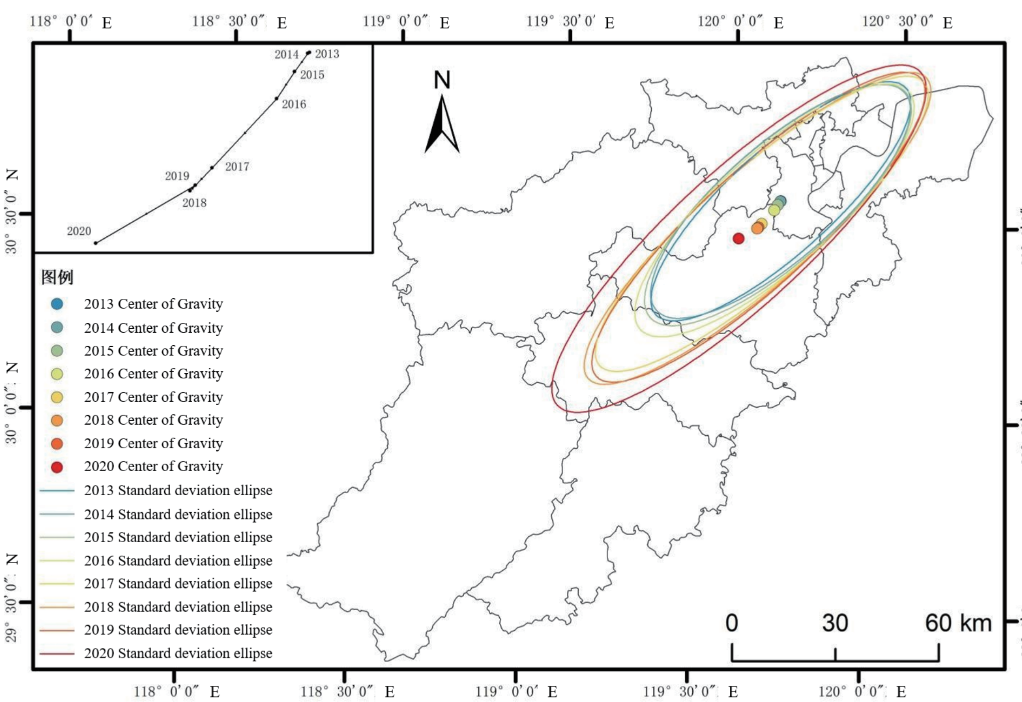


Fig. 2. (Color online) Standard deviation ellipses and centers of gravity of tourist density in Hangzhou from 2013 to 2020.

Table 1
Standard deviation ellipse characteristics and direction of change of tourist density center of gravity in Hangzhou from 2013 to 2020.

Year	Coordinates of center of gravity	Long half axis (km)	Short half axis (km)	Azimuth (°)	Direction of change
2013	120.037°E, 30.187°N	48.906	15.015	47.962	
2014	120.036°E, 30.187°N	47.86	16.519	48.911	Southwest
2015	120.026°E, 30.179°N	49.382	16.707	48.722	Southwest
2016	120.013°E, 30.167°N	51.972	16.648	48.588	Southwest
2017	119.967°E, 30.139°N	62.415	16.150	49.036	Southwest
2018	119.892°E, 30.112°N	71.412	19.308	47.580	Southwest
2019	119.958°E, 30.132°N	63.823	16.509	47.470	Northeast
2020	119.952°E,30.129°N	65.572	16.268	48.514	Southwest

To summarize, in the past 10 years, starting from the original tourism core in the eastern urban area, Hangzhou has formed new tourism hotspots in the western suburbs. With the general trend of yearly increases in the number of tourists, the spatial concentration of tourists has decreased, and the number of tourist destinations available for tourists in Hangzhou has increased.

3.3 Analysis of evolutionary trend of spatiotemporal distribution

The gray system forecasting method does not require a large amount of time series data to obtain accurate results,[17] and it has been practically and effectively applied in the prediction of tourist distributions.[18,19] In this paper, we use the *x*- and *y*-coordinates of the centers of gravity of the standard deviation ellipses of the tourist density in Hangzhou from 2013 to 2020 as the original data and construct a GM(1,1) prediction model to forecast the centers of gravity from 2021 to 2025.

To ensure the feasibility of the gray system forecasting method, it is necessary to perform a test on the known data. Assuming that there are data $x^{(0)} = (x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n))$, we calculate the step ratio of the series,

$$\lambda(k) = \frac{x^{(0)}(k-1)}{x^{(0)}(k)},\ k = 2,3,\ldots,n. \tag{6}$$

If all the step ratios $\lambda(k)$ are within the interval $(e^{-\frac{2}{n+1}}, e^{\frac{2}{n+1}})$,[20] then the data are suitable for prediction. The calculation shows that all the step ratios of the Hangzhou city data from 2013 to 2020 lie within the (0.801, 1.249) interval, which indicates that the data are suitable for constructing a gray system forecasting model (Table 2).

Usually, a relative error of less than 20% indicates a good fit, and the average relative errors of this model are 0.026 and 0.072%. As shown in Table 3, the constructed gray system prediction model fits the data well and can be used for subsequent predictions.

Table 2
Step ratio test results.

Year	Original value of x-coordinate	Step ratio	Original value of y-coordinate	Step ratio
2013	120.037	—	30.187	—
2014	120.036	1	30.187	1
2015	120.026	1	30.179	1
2016	120.013	1	30.167	1
2017	119.967	1	30.139	1.001
2018	119.892	1.001	30.112	1.001
2019	119.956	0.999	30.132	0.999
2020	119.952	1	30.129	1

Table 3
Backtest and residual test results of tourist density distribution model in Hangzhou.

Year	x-coordinate				y-coordinate			
	Original value	Predicted value	Residual	Relative error (%)	Original value	Predicted value	Residual	Relative error (%)
2013	119.765	119.765	—	—	30.064	30.064	—	—
2014	119.757	119.754	0.003	0.002	30.063	30.058	0.005	0.017
2015	119.766	119.718	0.048	0.04	30.075	30.039	0.036	0.12
2016	119.697	119.681	0.016	0.013	30.021	30.02	0.001	0.003
2017	119.568	119.645	−0.077	0.064	29. 95	30.001	−0.051	0.171
2018	119.566	119.609	−0.043	0.036	29.947	29.982	−0.035	0.118
2019	119.570	119.572	−0.002	0.002	29.972	29.963	0.009	0.029
2020	119.592	119.536	0.056	0.047	29.98	29.944	0.036	0.119

Table 4
Prediction results of GM (1,1) model for center of gravity coordinates.

Forecast year	x-coordinate of predicted value	y-coordinate of predicted value	Direction of change
2021	119.499	29.925	Southwest
2022	119.463	29.906	Southwest
2023	119.427	29.887	Southwest
2024	119.390	29.869	Southwest
2025	119.354	29.850	Southwest

The results of the GM(1,1) gray system prediction model are shown in Table 4. From 2021 to 2025, the center of gravity of the tourist density is predicted to continue moving southwest year by year, and the "westward" trend of tourists will become increasingly pronounced.

4. Influencing Factors and Their Interactions

4.1 Data sources

From the existing research results, we determined the importance of the following factors affecting the spatiotemporal distribution of tourists: tourism resource endowment, economic development level, tourism demand scale, relevant policy support, the number of service providers, and tourist reception capacity. We took the tourist volume of each A-class scenic spot in Hangzhou as the dependent variable y and the factors affecting the spatiotemporal distribution of tourists as the detection factors. After the data were processed according to the classification optimization algorithm, GeoDetector was used to explore the strength of the effect of each factor.

In this paper, the number of A-grade scenic spots was selected as a proxy for tourism resource endowment, where a larger number of tourism scenic spots with a high quality grade indicates a higher quality and greater richness of tourism resources. We used the gross regional product to measure the economic development level of Hangzhou districts and counties, which is an important reference value for evaluating the development of various industries and the overall economic strength of a region; destinations with good economic conditions are more attractive for tourism. With the expansion of the tourism consumption market and the increasingly convenient access to tourism information, the threshold for participation in tourism activities has been lowered, and local residents account for a larger proportion of tourists. Thus, the population in each district and county can, to a certain extent, reflect the total tourism demand in the region and measure the scale of tourism demand. The numbers of star-rated hotels and travel agencies are representative statistics of the tourist reception capacity and service agencies, respectively. The government can formulate the optimal development planning strategy for the development of tourism through administrative means. We counted the numbers of regulatory documents, government services, announcements, and other policy information of each district and county and measured the policy support factors accordingly. The above data were obtained from *Hangzhou Statistical Yearbook* and *Hangzhou Tourism Overview* from 2013 to 2020, and the policy information was queried from the website of the People's Government of Zhejiang Province.

4.2 q-value detection results

The p-values of the six detection factors are all in the range of 0.000–0.125, which indicates that the data are reliable. The results are shown in Table 5, which are ranked in the descending order of the q-value of each detection factor, i.e., its strength in explaining the spatiotemporal distribution of tourist density.

The results show that the most important factor affecting the tourist distribution in Hangzhou within the last decade is the number of service providers (0.749), the least important factor is the

Table 5
Impact factor detection indicator system and its explanatory strength.

Detection factor	Detection indicator	q-value	p-value
Number of service providers x_6	Number of travel agencies	0.749	0.000
Tourism demand scale x_3	Number of people in region	0.450	0.000
Economic development level x_2	Gross regional product	0.344	0.000
Relevant policy support x_4	Number of policy information	0.311	0.000
Tourist reception capacity x_5	Number of star-rated hotels	0.302	0.002
Tourism resource endowment x_1	Number of A-class scenic spots	0.143	0.125

tourism resource endowment (0.143), and the other factors are explained by the tourism demand scale (0.450), economic development level (0.344), relevant policy support (0.311), and tourist reception capacity (0.302).

The results of GeoDetector indicate that, in terms of single factors, the number of service providers is the most important factor affecting the evolution of the spatiotemporal distribution of tourists in Hangzhou. Tourism service agencies both provide a reliable source of information for tourists and act as organizers of tourism activities. These service providers combine multiple tourism products and resources to reduce the cost of travel for tourists while enhancing their travel experience. Therefore, they are the most important factor affecting the willingness of tourists to visit and revisit the area. Although tourism development has entered the era of personalization, travel agencies and other service providers still play an important role in the spatial and temporal aggregations of tourists.

Tourism demand is the desire of tourists to purchase tourism products,(21) and the economic development level reflects the purchasing power of tourists. The reason why these two factors have less effect than the number of service providers is that short-distance tourists have similar life backgrounds and economic power; thus, their motivation and ability to pay when making travel decisions do not differ significantly. For tourists from more distant origins, the impact of both factors will be greater. Provincial tourism policies such as the "Westward Policy", the construction of rural tourism facilities, and standardized operations have important effects on the development of tourism in Hangzhou, and the detailed targeting of policies at the municipal level has positively driven the implementation of specific initiatives in the tourism industry. As a result, relevant policy support also has some effect on the spatiotemporal changes of tourist flows.

On the other hand, with the increasing popularity of short-distance tourism such as suburban tours, same-day round-trip tourism has reduced the demand for accommodation and has a low impact on the tourism reception capacity. The attractiveness of a single form of generalized landscape to tourists has decreased.(22) With the abundance of urban recreational facilities, tourists are paying less attention to natural tourism resources when deciding tourist destinations. In contrast, interest in specialist forms of tourism such as cultural tourism, Chinese medicine tourism, and industrial tourism has increased, reducing the effect of tourism resources in the traditional sightseeing tourism model. Therefore, tourism resource endowment was the weakest factor among the selected influencing factors.

4.3 Analysis of effect of interaction between factors

Most of the previous studies on the factors affecting the spatiotemporal distribution of tourists have a single-factor perspective with little exploration of the change in the strength of influence due to the interaction between different factors. Using the interaction detection function of GeoDetector, we evaluated the explanatory strength of two influencing factors together and thus determined whether the effects of each influencing factor on the dependent variable are independent. The results of the pairwise interactions of the six detection factors are shown in Table 6.

Table 6
Results of the interactions of detection factors.

Interaction	q-value	Interaction result	Interaction	q-value	Interaction result
$x_1 \cap x_2$	0.556	Nonlinear enhancement	$x_2 \cap x_6$	0.871	Two-factor enhancement
$x_1 \cap x_3$	0.649	Nonlinear enhancement	$x_3 \cap x_4$	0.895	Nonlinear enhancement
$x_1 \cap x_4$	0.662	Nonlinear enhancement	$x_3 \cap x_5$	0.792	Nonlinear enhancement
$x_1 \cap x_5$	0.718	Nonlinear enhancement	$x_3 \cap x_6$	0.783	Two-factor enhancement
$x_1 \cap x_6$	0.779	Two-factor enhancement	$x_4 \cap x_5$	0.804	Nonlinear enhancement
$x_2 \cap x_3$	0.699	Two-factor enhancement	$x_4 \cap x_6$	0.911	Two-factor enhancement
$x_2 \cap x_4$	0.763	Nonlinear enhancement	$x_5 \cap x_6$	0.930	Two-factor enhancement
$x_2 \cap x_5$	0.813	Nonlinear enhancement			

The results show that there are two types of interactions between the independent variables. One is nonlinear enhancement, where $q(x_1 \cap x_2) > q(x_1) + q(x_2)$, the other is two-factor enhancement, where $q(x_1 \cap x_2) > \max(q(x_1), q(x_2))$, indicating that there is an intrinsic correlation between the effects of each factor on the spatiotemporal variation of Hangzhou tourism. The effects of each factor on the spatiotemporal variation of the tourist distribution in Hangzhou are intrinsically correlated, and the strength of explanation is enhanced after pairwise interactions of the detection factors. The interaction between x_6 (number of service providers) and x_5 (tourist capacity) is the most significant (0.930), followed by the interaction between x_6 (number of service providers) and x_4 (related policy support) (0.911), which has an explanatory strength of also more than 0.900. The third most significant interaction is between x_3 (tourism demand scale) and x_4 (related policy support) (0.895). Compared with that of the single-factor effect, the strengths of the effects of x_1 (tourism resource endowment) and other factors after the interaction are significantly high. However, there is still a gap between this factor and the other factors, and the strength of the explanation after the interaction is still the lowest.

According to the results of the interactions among various factors, the number of service providers and the tourist reception capacity have the greatest impact on the spatiotemporal distribution of tourists after the interactions. The integration and linkage of travel agencies, service stations, hotels, homestays, and other relevant social resources inject vitality into the tourism economy, promoting the transformation and upgrading of overall tourism service facilities and the evolution of the spatial distribution of tourists. In addition, the effect of policy support as a single factor is limited, but it can play an auxiliary role in the interaction of factors. The government can proceed from the overall situation and achieve resource integration through unified planning, so as to maximize the efficiency and cohesion of the resultant tourism development. It has promoted the integration of its tourism industry, cultural industry, leisure sports, and other industries and comprehensively improved the quality of its tourism services, resulting in an increase in the number of tourists.

Overall, the combination of factors after their interaction strengthens the effect on the spatiotemporal distribution of tourists. Nowadays, tourists' requirements are more diverse, and the coordination of multisectoral resources can effectively increase the willingness of tourists to travel. Under the guidance of the government's overall planning, Hangzhou has cultivated tourism demonstration areas with distinctive features and built tourism towns based on natural and humanistic landscapes. The variety of tourism and leisure products has become richer, and the categories and quality of tourism facilities have been significantly improved. Under the combined effect of many factors, the area of Hangzhou with a high density of tourists has increased.

5. Conclusion

We visualized and analyzed the spatiotemporal evolution of tourists in Hangzhou in the last decade by using the research methods of kernel density analysis, standard deviation ellipses, and gray system prediction. The strength of each influencing factor in explaining the variation in the spatiotemporal distribution of tourists was measured using GeoDetector. The following main conclusions were obtained.

First, the spatial distribution of tourists in Hangzhou is dense in the northeast and scattered in the southwest. Over time, the distribution has changed from a single core with a high density of tourists to multiple cores. On the basis of the high-density area in the main urban area, new dense areas have gradually formed in the northeast of Yuhang District, the north of Tonglu County, the main coast of Qiandao Lake Reservoir, and the southwest of Qiandao Lake. The center of gravity of the distribution of tourists has continued to move southwest, the area of the standard deviation ellipse has increased, and the difference between the distances of the long and short semi-axes has increased. These findings indicate that the tourism potential of the western part of Hangzhou has been explored and developed in the past ten years, and the overall spatial concentration of the tourist distribution has been reduced. It is predicted that tourists will be more inclined to choose destinations in the western part of the city in the future and that the trend of the westward flow of tourists will continue.

Second, the evolution of the spatiotemporal distribution of tourists is affected by a variety of factors. The number of service providers is the strongest influencing factor, followed by the scale of tourism demand, while the strength of the effect differs little between the economic development level, relevant policy support, and tourist reception capacity. Tourism resource endowment is the least influencing factor. After examining the interactions between the factors, we found that the interaction between the number of service institutions and the tourist reception capacity has the strongest effect on the tourist distribution. Tourism resource endowment has a significantly stronger effect when its interactions with the other factors are included. Overall, the combination of all factors after their interaction strengthened the effect on the spatiotemporal distribution of tourists. The future development of tourism destinations should be planned in a holistic manner by considering the factors affecting the tourist spatiotemporal distribution and promoting the mutual complementarity and mutual promotion among the influencing factors. Such an approach will create a more dynamic environment with a balanced spatiotemporal distribution of tourists.

Acknowledgments

This work was supported by the General Program of National Natural Science Foundation of China (Grant No. 42271255) and the Humanities and Social Sciences Research Project of the Ministry of Education (Grant No. 21YJA790052). The authors wish to thank the two anonymous reviewers for their constructive comments on this manuscript.

References

1 F. Yan, L. Lei, J. Jiang, J. Su, and X. Xu: Ecol. Econ. **S1** (2004) 208. https://doi.org/CNKI:SUN:STJJ.0.2004-S1-062
2 M. A. Bonn, H. K. Furr, and M. Uysal: J. Travel Res. **31** (1992) 50. https://doi.org/10.1177/004728759203100110
3 A. Rein, A. Anto, M. Ülar, P. Taavi, K. Ain. Tour. Manage. **28** (2007) 898. https://doi.org/10.1016/j.tourman.2006.05.010
4 A. d. Benedetto and D. C. Bojanic: Ann Tourism Res. **20** (1993) 557. https://doi.org/10.1016/0160-7383(93)90009-R
5 Y. Zheng, N. Mou, L. Zhang, T. Makkonen, and T. Yang: Comput. Environ. Urban Syst. **85** (2021) 101561. https://doi.org/10.1016/j.compenvurbsys.2020.101561
6 D. Tsiotas, T. Krabokoukis, and S. Polyzos: Tour. Hosp. **2** (2021) 113. https://doi.org/10.3390/tourhosp2010007
7 M. Long, G. Sun, L. Ma, and J. Wang: Areal Res. Dev. **30** (2011) 93. https://doi.org/10.3969/j.issn.1003-2363.2011.03.019
8 L. Ren and D Cui: Inquiry Econ. Issues **4** (2014) 67. https://kns.cnki.net/kcms/detail/detail.aspx?FileName=JJWS201404012&DbName=CJFQ2014
9 G. Sun and L. Ma: Tourism Tribune **7** (2007) 34. https://doi.org/10.3969/j.issn.1002-5006.2007.07.010
10 Q. Li, G. SUN, and Y. Han: J. Arid Land Resour. Environ. **5** (2008) 101. https://doi.org/10.3969/j.issn.1003-7578.2008.05.020
11 J. Yao: The Merchandise Quality **3** (2020) 6. https://www.zhangqiaokeyan.com/academic-journal-cn_the-merchandise-quality_thesis/0201278424020.html
12 Q. Zhang: Advanced Econometrics and Stata (Higher Education Press, Beijing, 2014) 2nd ed., p. 520.
13 L. Zhao and Z. Zhao: Sci. Geogr. Sinica **34** (2014) 979. https://doi.org/10.13249/j.cnki.sgs.2014.08.015
14 L. Zhao, Z. Zhao, and W. Wang: Econ. Geogr. **34** (2014) 14. https://doi.org/10.15957/j.cnki.jjdl.2014.02.020
15 J. Wang and C. Xu: Acta Geogr. Sinica **72** (2017) 116. https://kns.cnki.net/kcms/detail/detail.aspx?FileName=DLXB201701011&DbName=CJFQ2017
16 J. Wang, M Huang, and Y Liu: GAGIS **31** (2015) 102. https://doi.org/10.3969/j.issn.1672-0504.2015.05.021
17 M. Nai and S. Liu: Syst. Eng. Theor. Pract. **25** (2005) 93. https://doi.org/10.3321/j.issn:1000-6788.2005.01.014
18 X. Zhu, X. Yang, and Y. Cai: Econ. Geogr. **25** (2005) 232. https://doi.org/10.3969/j.issn.1000-8462.2005.02.022
19 M. Yang and X. Yang: J. Southwest China Normal Univ. (Natural Science Edition) **25** (2005) 259. https://doi.org/10.3969/j.issn.1000-8462.2005.02.022
20 N. Zhou: J. Shandong Univ. Finance Econ. **6** (2013) 89. https://kns.cnki.net/kcms/detail/detail.aspx?FileName=SDCY201306013&DbName=CJFQ2013
21 F. Liu: J. Dezhou Univ. **20** (2004) 81. https://doi.org/10.3969/j.issn.1004-9444.2004.04.024
22 P. Lei and Z. Shi: Human Geogr. **24** (2009) 102. https://kns.cnki.net/kcms/detail/detail.aspx?FileName=RWDL200901025&DbName=CJFQ2009

About the Authors

Yue Wang received her B.S. degree from Jinan University, China, in 2021. She is currently a business administration graduate student of Beijing Union University. Her research interests are in industrial heritage tourism. (wangyue@163.com)

Qiuju Wang received her Ph.D. degree from Northeast Agricultural University, China, in 2007. She is currently a professor in the School of Tourism of Beijing Union University. Her research interests are in industrial heritage tourism and tourism economy. (wqiuju@126.com)

Zhaoyun Zhong received her B.S. degree from Beijing Union University, China, in 2022. Her research interests are in tourism economy and sensors. (z635107862@sohu.com)

Xiaorui Zhang received his B.S. degree from Shanxi University of Finance and Economics University, China, in 2022. He is currently a postgraduate at Beijing Union University, China. His research interests are in industrial heritage tourism, industrial tourism, and place meanings. (20221120210522@buu.edu.cn)