Spatial-Temporal Analysis of Street Patrol Cases in Zhengzhou, China, Using Getis-Ord Gi* and Space-Time Cube

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Abstract. Urban management is an important content of social management, which is related to people's livelihood and social harmony. With the rapid advancement of urbanization and the continuous expansion of urban scale, urban management faces greater challenges, and it is very important to complete urban management efficiently and effectively. The purpose of this study is to analyse the spatiotemporal characteristics of street patrol cases in Zhengzhou, China. A statistical approach is used for overall analysis, then analysis method of Getis-Ord Gi* and space-time cube are used. Focusing on smart city management work in the central city of Zhengzhou, the study examines street patrol cases in the categories of urban environment and street order. The main findings are as follows: The analysis by the space-time cube model shows that street order case hotspots have seasonal characteristics on monthly data. The urban environment cases have a wider distribution and higher density during winter near the Chinese New Year.

Keywords: Street patrol cases · Spatial-temporal analysis · Getis-Ord Gi* · Space-time cube

1 Introduction

With the rapid development of urban modernization and the continuous gathering of various social elements in the city, the complexity of urban management issues has increased 1. Digital city management, which is biased toward data collection and delivery, seems to be lacking in motivation. Compared with digital city management, smart city management focuses more on the discovery of information in urban management problems. This transformation deepens and develops digital city management, and intelligent city management is enhanced on the basis of digital city management in the city system 2. In this context, it is important to study the accumulated data of street patrol cases in the intelligent city management system. This can guide the decisions of the city management department. The patrollers find problems in urban construction such as il-legal

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operations and road occupation by street patrol 3. The space-time cubemodel proposed by Hagerstrand et al. has been widely used in traffic safety and crime patrol 4. Beconyte et al. used the space-time cube to model violent crime in Lithuania 5, and Cheng et al. used the space-time cubeto analyse the spatial-temporal distribution of traffic accidents at road intersections in Wujiang city 6. Therefore, the spatial distribution of street patrol cases can be analysed by space-time cube, which can simply verify point da-ta density or clustering and identify regional hotspots and potential clusters in the paper. Then, 3D geovisualization can show spatial patterns, spatial relationships and changes over time. The space-time cube shows the potential to identify and evaluate spatiotemporal patterns 7. In this study, the spatiotemporal characteristics and changes in street patrol case data in Zhengzhou city are visualized and analysed using space-time cube.

2 Materials and Methods

2.1 Data and Study Area

Zhengzhou is located in central China, with the Yellow River to the north, the Song Mountains to the west and the Yellow and Huai Plains to the southeast. Zhengzhou city has six districts, including Zhongyuan District, Erqi District, Jinshui District, Guancheng Huizu District, Huijie District, Gaoxin District, Zhengdong New District and Aviation Port District. The total area of Zhengzhou City is 7446.2 km^2, and the urban area is 1010.3 km^2.

This study takes the coverage area managed by the city management system of Zhengzhou as the study area, covering an area of approximately 567 km2. It includes the six administrative districts within the East 4th Ring Road, South 4th Ring Road, West 4th Ring Road and the 4th Ring Road surrounded by Dahe Road. The data of street patrol cases are analysed for the 2018 road network data in the city. The case information contains nonspatial attributes such as case code, category, and situation description, as well as spatial attributes such as location coordinate values and temporal attributes such as time of occurrence. In 2018, there were 1,003,808 street patrol cases that occurred in Zhengzhou City, which were divided into the categories of Urban environment and Street order, Emergencies, Publicity and Advertising, and other cases 1. The time window of urban management data used in this study spans the entire year from January 2018 to December 2018. The total number of records is 1,048,575. Cases in the categories of urban environment cases and street order cases were selected for study.

2.2 Methods

Getis-Ord Gi* analysis is a hotspot analysis of high-density areas of cases from a statistical perspective and is used to identify the locations of statistically significant characteristic hot or cold spots 8. The spatiotemporal cube method is a three-dimensional technique. The spatiotemporal activity of the case is characterized by conceptualizing a two-dimensional graph plus a third dimension, i.e. the temporal dimension 9. This method uses the geometric properties of the temporal dimension and the concept of a spatial entity as a spatiotemporal body, which provides a simple, straightforward and easy-to-accept description of geographic changes. The three-dimensional cube consists of a space-time box, with the x and y dimensions representing space and the t dimension representing time. Each box has a fixed position in space (x, y) and time (z). By constructing a spatiotemporal cube, a more intuitive expression of the results is formed to provide an intuitive reference for studies related to spatiotemporal analysis 10.

In this paper, we set 340 m after creating a spatial weight matrix and determining a maximum spatial autocorrelation value. This represents the distance at which these spatial processes are most active. A spatial cube model with spatial values (x, y) of 340m grid spatial extent and 2 h interval time dimension interval is constructed. It is calculated by dividing the longest edge of the study area by the width of the average spatial envelope range at the block scale.

3 Results

To analyse the trend of street patrol cases in Zhengzhou City in 2018, the spatial unit of the space-time cube is set to 340 × 340 m, and the monthly box is generated for the time unit. The results of the spatiotemporal cube model analysis in Fig. 1 show that the spatial distribution of both the urban environment category cases and the street order category city management cases unfolded sequentially to the periphery along the main road network in Zhengzhou. The intersection of the administrative divisions of the central city interface frequent multitemporal frequent occurrence of various types of cases, and the side of the city management of the central city along the main street space has more management problems. This should strengthen the work of the city environment category of cases on the main and secondary roads and major feeder roads within the fourth ring and remove the street order category of problems along the main and secondary roads.

Figure 1 shows details of the analysis of the trends in each bin when the 3D cube is represented in two dimensions. Each bin in the time cube has a LOCATION_ID, time_step_ID, COUNT value and any aggregated fields or variables that were aggregated at the time of cube creation. Bins associated with the same physical location will share the same location ID and collectively represent a time series11. The bins associated with the same time step interval share the same time step ID and together form a time slice. The count value of each bin reflects the number of cases or records that occurred at the relevant location during the relevant time step interval (Fig. 2).

Getis-Ord Gi* analysis tools can detect eight specific hot or cold spot trends: new, continuous, intensified, persistent, decreasing, sporadic, oscillating and historical data with multiple description types1213. The trends in the categories of urban environment cases and street order cases using Getis-Ord Gi* analysis are shown in Figs. 3 and 4. The spatial and temporal patterns of the two types of cases were analysed similarly, and the results indicated that the main type of central area in the old city of Zhengzhou is an oscillating cold spot, and the concentrated high incidence of urban environmental cases was located at the urban boundary junction of Zhongyuan District, Erqi District, Guancheng District and Jinshui District. There is a step transition region at its periphery be-longing to the sporadic cold spot region. Farther outward, there is an obvious event-time persistent cold spot gathering area (persistent cold spot). There is an enclave area

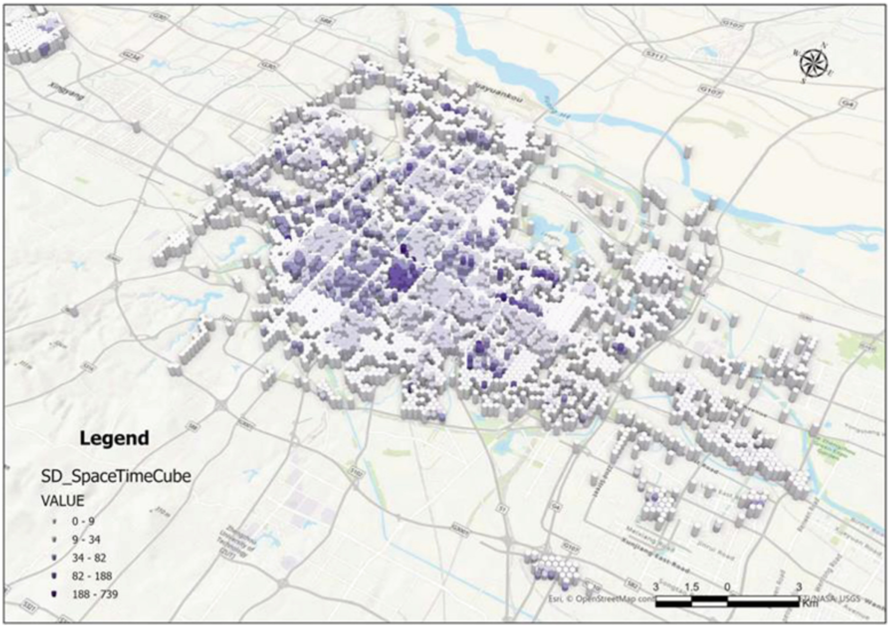

Fig. 1. Details of generated space-time cube

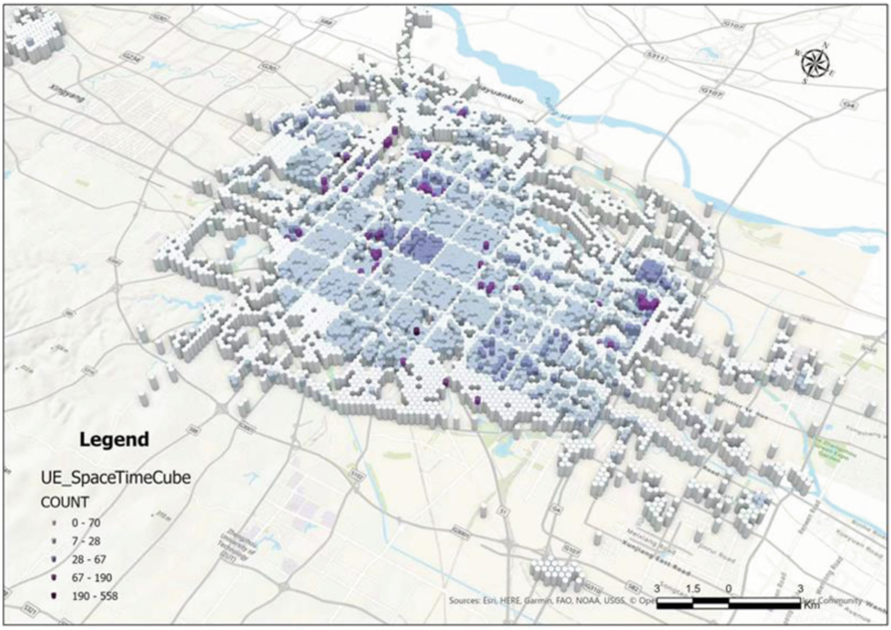

Fig. 2. Details of generated space-time cube

of oscil-lating cold spots at Zhengzhou Zhengxin Airport, and persistent cold spots are mainly distributed at the edge of the central city and the peripheral area.

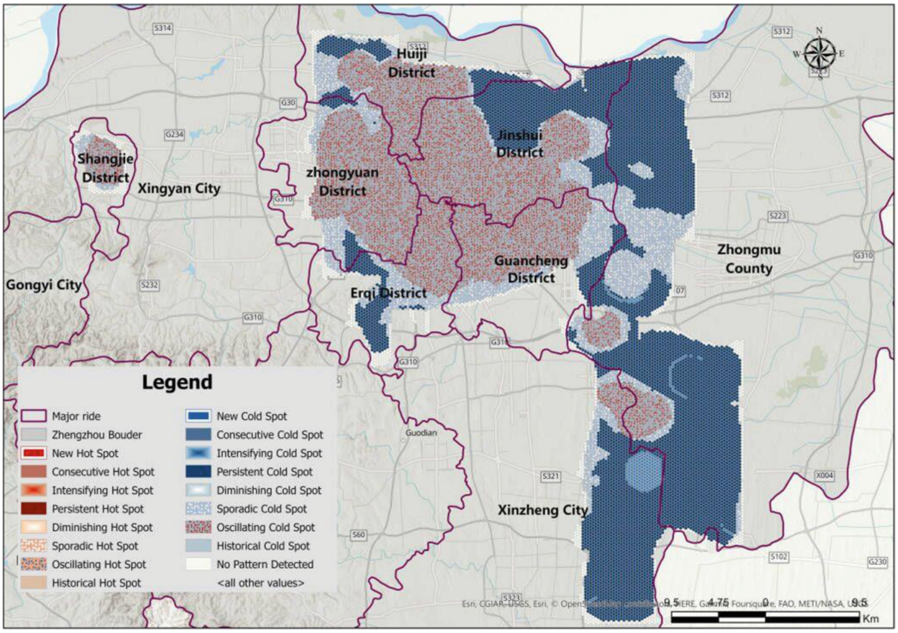

Fig. 3. Trends in urban environment cases using emerging hot spot analysis

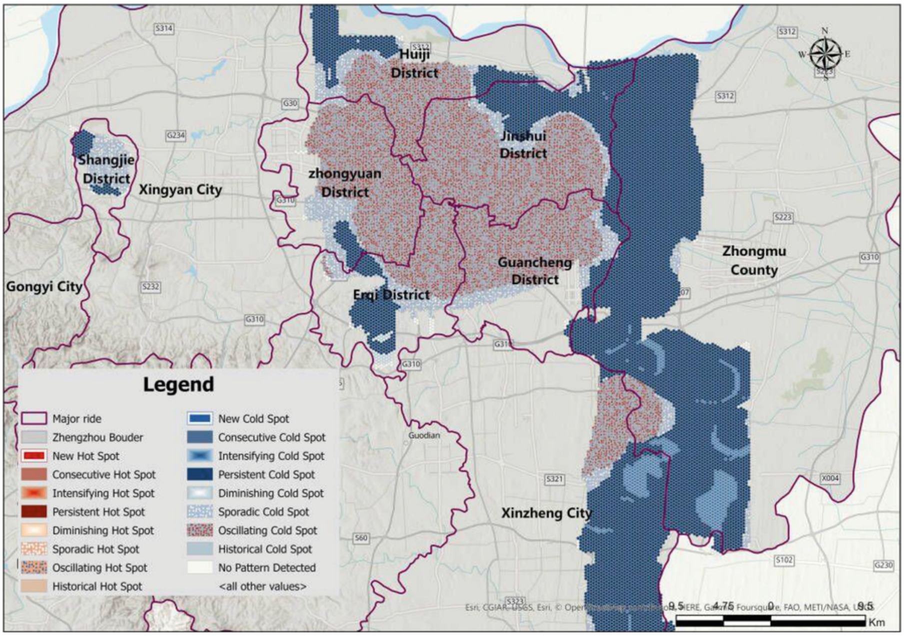

Fig. 4. Trends in street order cases using emerging hot spot analysis

4 Conclusions

According to the analysis of the hotspot spatial and temporal characteristics of urban patrol cases, for urban environmental cases, the management resources are more inclined to be arranged in the core traffic space and its surrounding areas. The peripheral space of the city can be appropriately less resource input, and the management resources are given to the corresponding area according to the seasonal characteristics to supplement. For street order cases, it is necessary to give priority supervision to the street space near school sites and residential sites to effectively allocate urban patrol management resources. In urban planning, the supporting planning layout is functional, and the corresponding public facility space highlights the corresponding urban cases and problems. As public welfare facilities have been planned that temporarily fail to ensure that the construction is in place, there are urban management problems. Therefore, through spatial statistics and analysis, the management resources are distributed according to the seasonal characteristics of the city environment problems under the premise of delineating the management scope. For street order cases, we allocate management resources to urban land and functional zones during peak hours to solve the mismatch of management resources.

Further research is needed with regard to digital city management case analysis. This will advance research in the following directions. (1) On the basis of city operation and management, the theoretical basis of data mining for the spatiotemporal business of intelligent city management was constructed under the framework of digital twin theory combined with the actual operation of digital city management systems. (2) Preprocessing of the study data. The case data were diluted based on the responsible grid distribution and time period to reduce the data volume. The study used an offline compression strategy to process the original trajectory data and compress the trajectory data. The coordinate aver-aging method was used to identify and eliminate the noise points in the trajectory to reduce the number of coordinate points in the trajectory data.

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