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Research on Spatial Optimization and Functional Layout Model of Urban Buildings Based on Big Data Analysis

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Abstract: A spatial optimization and functional layout model of urban buildings is based on big data analysis to address the limitations of traditional urban planning methods in dealing with urban complexity and dynamics. By integrating multi-source data, including mobile positioning, building use, environmental monitoring, population statistics and traffic flow, using data cleaning, integration and storage technology, combining machine learning algorithm and GIS spatial analysis technology, a scientific and effective model framework for urban building spatial optimization and functional layout is constructed. Taking a big city as an example, the key features are extracted by principal component analysis (PCA) and cluster analysis, and the random forest algorithm is used to optimize the model, and the architectural space optimization scheme for this city is put forward. The results show that after optimization, the urban traffic congestion index decreased by 38.79%, the average commuting time shortened by 22.97%, the air quality index increased by 25.90%, the green space coverage increased by 37.91%, and the residents' satisfaction increased by 21.51%. The research shows that big data analysis technology can provide scientific basis for urban planning, improve the accuracy and effectiveness of urban planning, and provide new ideas and methods to solve the problems of uneven spatial distribution and unreasonable functional layout of urban buildings.

1. Introduction

Traditional urban planning methods often rely on empirical judgment and qualitative analysis, and it is difficult to comprehensively and accurately reflect the complexity and dynamics of urban architectural space and functional layout. The emergence of big data analysis technology provides a new perspective and means for urban planning.

Big data analysis technology can reveal the inherent laws and characteristics of urban architectural space and functional layout by mining and processing massive data, and provide scientific basis for urban planning [1]. For example, the data of mobile positioning equipment can analyze the characteristics of urban population flow and distribution, and provide reference for the layout of commercial facilities and service facilities; Through the sensor network data, we can monitor the urban environmental quality and traffic flow, and provide the basis for the planning of urban green space and traffic facilities [2].

However, although the application of big data analysis technology in urban planning has achieved certain results, its application in the optimization of urban architectural space and functional layout is still in the exploratory stage. How to make full use of the advantages of big data analysis technology to build a scientific and effective model of urban building space optimization and functional layout has become an urgent problem. Therefore, this paper reveals the laws and characteristics of urban architectural space and functional layout by mining and processing the big data related to urban architecture, and provides scientific basis and reference for urban planning.

2. Model construction

2.1. Model frame

Through the analysis of massive data, urban planners can understand the laws of urban operation more accurately and make more scientific and reasonable decisions. The application of big data technology in urban traffic flow monitoring is mainly reflected in the real-time monitoring and prediction of traffic flow. Traffic flow data can be collected in real time through various sensors and cameras installed on the road. Using machine learning and data mining technology, we can analyze these data, predict the future traffic situation, and provide a basis for traffic management and planning [3]. For example, the analysis and prediction of urban traffic flow based on big data can help urban managers optimize traffic signal control strategies and reduce traffic congestion.

The application of big data analysis in population migration trend analysis is mainly reflected in the mining of population migration laws and trends [4]. By analyzing cell phone signaling data and social media data, we can understand the migration patterns and trends of the population. This is very important for urban planners, because population migration directly affects the allocation of public resources such as housing, education and medical care in cities [5]. The analysis of population mobility based on big data can help the government to take corresponding measures at the peak of population mobility, such as increasing employment opportunities and optimizing the allocation of public service resources [6-7].

The application of big data analysis in the optimization of urban green space layout is mainly reflected in the scientific planning and management of urban green space. Through the mining and analysis of urban greening data, we can optimize the spatial structure of green space, improve ecological functions, innovate landscape design and improve urban quality [8]. The analysis and layout update of urban green space based on POI big data can effectively reduce the problem of "spatial mismatch" in urban park planning, and realize social equity and the recreation needs of people within the scope.

This paper designs a model framework for spatial optimization and functional layout of urban buildings based on big data analysis, which provides scientific and effective architectural spatial optimization and functional layout schemes for urban planning by mining and processing big data related to urban buildings. The model framework mainly includes several parts as shown in Figure 1.

Through API interface, sensor network and remote sensing technology, multi-source data including mobile positioning, building use, environmental monitoring, population statistics and traffic flow are collected. Cleaning, integration and storage are carried out in the data processing stage to ensure the quality of data and form a unified format for analysis. In the model construction layer, the characteristics related to urban planning are extracted, and the model is trained by machine learning algorithm, and the effectiveness of the model is verified by actual or simulated data. Finally, based on the trained model, the optimization scheme is generated and visualized to help urban planners make more informed decisions.

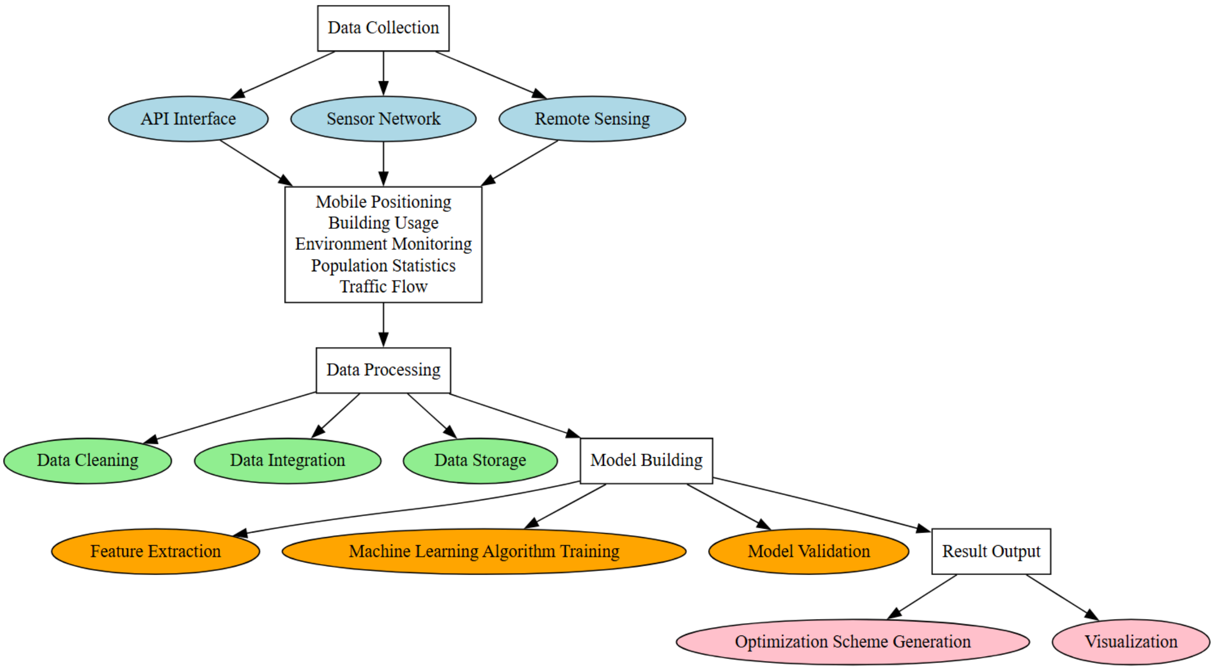

Figure 1 Spatial optimization and functional layout model framework of urban buildings based on big data analysis

2.2. Key algorithms and technologies

Comprehensive use of a series of key algorithms and technologies. Firstly, data cleaning tools such as Python Pandas library and data warehouse technology are used to clean and integrate data to ensure data quality and form a unified view. Then, the basic and deep features of the data are extracted by statistical methods and machine learning algorithms such as principal component analysis and cluster analysis. Then, the random forest algorithm is selected, and the parameters are optimized by cross-validation and grid search to improve the model performance. At the same time, GIS technology is used to analyze spatial data, and machine learning is combined to build a spatial optimization model to provide scientific support for urban planning. Finally, using visual tools such as Matplotlib and Seaborn, the optimization scheme is visually displayed in the form of maps and charts to assist the decision-making process of urban planners [9].

Based on big data analysis, the spatial optimization and functional layout model framework of urban buildings, combined with a variety of key algorithms and technologies, can fully mine and process big data related to urban buildings, and provide scientific and effective architectural spatial optimization and functional layout schemes for urban planning.

3. Case analysis

3.1. Case selection

The study selects a representative big city as a case, which has a long history and culture, and is also the center of modern economy, science and technology and culture. With the acceleration of urbanization, the city is facing the problems of uneven spatial distribution of buildings and unreasonable functional layout, such as traffic congestion caused by excessive concentration of commercial areas, and the mixed residential and industrial areas affecting the quality of life of residents. In order to solve these problems, this study decided to use the framework of urban building space optimization and functional layout model based on big data analysis to conduct in-depth research.

3.2. Data analysis

Through API interface, sensor network and remote sensing technology, the multi-source data of the city including mobile positioning, building use, environmental monitoring, population statistics and traffic flow are collected. Specific data include mobile phone signaling data to analyze population flow and distribution, building usage data to understand the functions and usage of various buildings, environmental monitoring data to grasp the urban environmental quality, demographic data to reflect the urban population structure and distribution, and traffic flow data to reveal urban traffic conditions.

Use Python's Pandas library and other data cleaning tools to clean the collected data, and remove duplicates, anomalies and missing data. Data warehouse technology is used to integrate data to form a unified data view, which is convenient for subsequent analysis.

The basic and deep features of data are extracted by statistical methods and machine learning algorithms (see Figure 2). Principal component analysis (PCA) is used to reduce the dimension of building usage data and extract the main building functional features. Cluster analysis is used to cluster the data of population flow, revealing the hot and cold spots of urban population distribution.

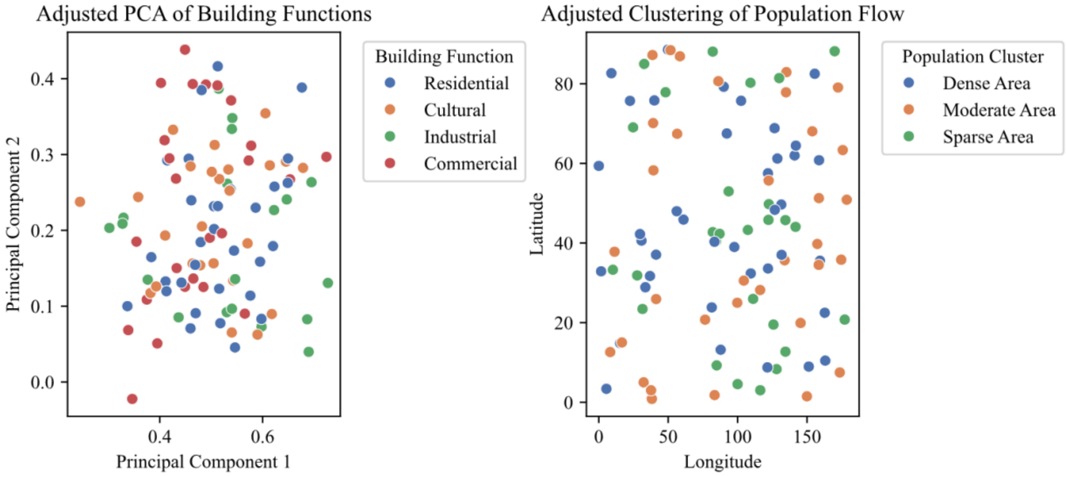

Figure 2 The main building functional characteristics are clustered with population flow data.

3.3. Model application

In the model construction layer, the characteristics related to urban planning are extracted, and the random forest algorithm is selected as the main algorithm for model training. The parameters of the algorithm are optimized by cross-validation and grid search, and the performance of the model is improved. At the same time, spatial data analysis is carried out with the help of GIS technology, and a spatial optimization model is constructed with machine learning. Based on the trained model, the optimization scheme of architectural space optimization and functional layout for the city is generated. The plan includes: adjusting the layout of the business district to alleviate traffic congestion; Optimize the distribution of residential areas and industrial areas to improve the quality of life of residents; Strengthen the construction of urban green space and improve the quality of urban environment.

Urban traffic conditions, environmental quality and residents' satisfaction have all improved significantly (see Table 1). The traffic congestion index decreased from 6.78 to 4.15, an improvement of 38.79%; The average commuting time is reduced to 34.8 minutes, which is 22.97% shorter, and the traffic efficiency is effectively improved. The air quality index (AQI) dropped to 89.3, increasing by 25.90%, while the green space coverage rate increased to 25.1%, increasing by 37.91%, and the ecological environment was improved. The distance between the industrial zone and the residential zone has expanded to 3.02 kilometers, an increase of 97.39%, which is helpful to reduce the pollution impact of industry on residents' lives. In addition, residents' satisfaction rose to 85.3%, an increase of 21.51%, indicating that residents have higher recognition of the urban environment and quality of life.

Table 1 Comparison of key indicators before and after urban optimization

Key indicators	Before optimization	After the optimization	improvement rate
Traffic congestion index	6.78	4.15	38.79%
Average commuting time (minutes)	45.2	34.8	22.97%
AQI	120.5	89.3	25.90%
Residents' satisfaction (percentage)	70.2%	85.3%	21.51%
Green space coverage (percentage)	18.2%	25.1%	37.91%
Distance between industrial area and residential area (km)	1.53	3.02	97.39%

Based on big data analysis, we should strengthen data collection, integration and storage, and use API interface, sensor network and remote sensing technology to obtain high-quality unified format data. Secondly, explore the application of machine learning algorithm to build an optimization model to improve the scientificity and accuracy of planning. Finally, we attach importance to the application of GIS technology in spatial data analysis, build a spatial optimization model with machine learning results, and visually display the optimization scheme through visual tools to assist decision-making, thus improving the effectiveness of urban planning.

4. Conclusion

After cleaning, integrating and storing the data collected through API interface, sensor network and remote sensing technology, the key features are extracted by using statistical methods and machine learning algorithms. Random forest algorithm combines cross-validation and grid search to optimize parameters, which significantly improves the model performance. The introduction of GIS technology further enhances the ability of spatial data analysis and provides an accurate spatial optimization model for urban planning. Case analysis shows that the model framework has achieved positive results in practical application, which not only improves the traffic conditions and environmental quality of the city, but also improves the quality of life of residents. For example, the adjustment of the layout of the business district has effectively alleviated the traffic congestion, the rational distribution of residential areas and industrial areas has reduced the pollution impact, and the increase of urban green space has significantly improved the ecological environment. The improvement of residents' satisfaction further proves the effectiveness and practicability of the model. This study confirmed the potential of urban building space optimization and functional layout model based on big data analysis in improving the scientificity and effectiveness of urban planning. Future research should continue to explore more advanced data processing technologies and algorithms to further improve the accuracy and adaptability of the model and provide more powerful support for urban sustainable development.

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