Application of Big Data Visualization in Urban Planning

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Abstract. During the past ten years, with the process of urbanization accelerates, urban population has increased sharply. Traffic congestion, noise pollution, garbage treatment and other problems, which make the traditional urban planning methods difficult to shoulder this heavy responsibility. At the same time, intelligent city and the construction of informationize is also developing rapidly, the practice and research of big data in urban planning industry are widely used. Large scale data visualization is one of the most important steps in big data. Not only can the data be expressed in visible form to improve the efficiency of data analysis, but also human-computer interaction can be carried out. To overcome these problems, this paper studies the problem of urban planning based on large scale data visualization. Firstly, it extends the concept and model of big data visualization to the significance and framework of applying big data visualization to urban planning. Then through the case of visualization of traffic data and environmental sound data, we can see that both quality and efficiency have been significantly improved. Furthermore in order to stimulate future research in this field, we also highlight the major opportunities and challenges, as well as potential important research directions for urban planning.

1. Introduction

In recent years, with the prosperity of cities and the rise of economy, the problems and contradictions accumulated in the planning, construction and management of cities in China are becoming increasingly acute. Meanwhile, the new generation of information and communication technology, which is typical of big data, has been constantly integrated into all aspects of society. The visualization of big data has also been applied widely in the practice and research of urban planning industry [1].

Lack of data and duplication of data analysis in planning research, over-reliance on planners' personal experience in planning analysis, difficulties in matching planning in different scales of space, and lack of blueprint for realizing planning effect are all problems in traditional urban planning. The combination of urban planning and large scale data visualization, first of all, when creating design schemes and evaluating comparison schemes, the use of large data visualization technology can optimize different design schemes. Secondly, as far as the overall nature of urban planning is concerned, minor mistakes may make urban development stagnant or even retrogressive. Finally, the application of visualization technology in the field of planning and design can rationally allocate resources, improve the utilization rate of resources, and achieve higher economic benefits. Therefore, its application to planning, a resource-intensive industry, will greatly improve the degree of
informatization and digitalization of the city, so that urban development will achieve a new and rapid mode [2].

Rest of this paper is organized as follows. Section 2 introduces the concept and technology of big data visualization to extend the big data types and visualization technology involved in urban planning. Section 3 is an example of the application of traffic big data visualization and environmental big data visualization in urban planning. Section 4 looks forward to discussing the problems that should be paid attention to in better application of big data visualization in urban planning. Section 5 summarizes the foregoing and illustrates the necessity of large scale data visualization for urban planning from the perspective of urban development.

2. Driving mechanism of large data visualization in urban planning

2.1. Basic concepts of large data visualization

Visualization of large scale data is proposed by Professor Jim Thomas at the beginning of the 21st century. It is an indispensable technology in the analysis and application of big data mining. It is defined as displaying data on the screen in the form of graphics or images, expressing the characteristics of large scale data more intuitively and making it easy for people to observe. Visualization is not only a way of displaying calculation results, but also an effective means of data analysis and knowledge understanding. Generally speaking, large scale data visualization analysis is a method that takes visualization, automatic analysis algorithm and human-computer interaction as the main means to transform massive raw data into effective knowledge.

2.2. Big Data Types Involved in Urban Planning

City is a huge system with complex factors and interlacing effects. The relationship between the data to be taken into account and the need to be clarified in the governance process is complicated and confused [6]. Here we mainly introduce the application of three kinds of big data visualization in urban planning.

Traffic planning is the most common application area of urban big data visualization at present [7]: By visualizing and analyzing the trajectory of taxis, we can know the mode of urban economic activities to a great extent [8]. By comprehensively displaying the operational attributes of various aspects of public transport system, we can contribute to understand the mode and state of urban residents'travel [9]; and through the dynamic monitoring of traffic flow speed and flow, the real-time traffic situation can be grasped, and the reliable and safe operation of the traffic system can be guaranteed [10].

Urban environmental problems, especially the impact of urban environmental noise pollution, are becoming more and more serious. Noise pollution complaints always rank first in China's environmental complaints [11,12]. Routine detection and management of urban environmental noise generally relies on the drawing of noise maps: in 2002, Shanghai Academy of Environmental Sciences drew the first noise map of our country in combination with the environmental planning of Xuhui District at that time [13]; in 2008, Shenzhen Luosai Acoustic Technology Co., Ltd. drew the first noise map of urban area in China, which is about 12 square kilometers [14]. In 2009, the Beijing Institute of Labor Protection Sciences completed the first urban noise map of Beijing based on the existing traffic noise data.

Big data applied to urban morphology and structure include Internet open data, Baidu thermodynamic map, mobile signaling, etc. They can show function and spatial distribution by tracking population distribution and dynamic changes: Wu Zhiqiang and Ye Zhongnan based on the data of Baidu thermogram, the changes of the index of population concentration, the location of population concentration and the population center of gravity over time in a continuous week are analyzed.[16]; Li Juan and others combined with the perspective of human agglomeration, made use of Baidu Thermal Map data to classify multi-center cities at the national scale [17]; Zheng Xiaowei
took the main urban area of Xi’an as the research object, and proposed an identification and optimization method of urban center system based on open data [18].

2.3. Big Data Visualization Processing Technology in Urban Planning

Visualization technology is mainly divided into three research directions: scientific visualization, visual analysis and information visualization. The foundation of scientific visualization and information visualization is visual analysis technology, which extracts useful information from massive data by analyzing and reasoning technology, transformation technology, data representation and other data processing technology, and obtains a deeper understanding of complex problems [19].

When visualization technology is applied to urban planning, it will be combined with more technologies. Firstly, in the aspect of traffic management, the most widely used method is to integrate GIS (Geographic Information System) with computer technology to comprehensively manage spatial geographic information data [20]. Secondly, the dimension of urban big data is increasing, the multi-dimensional overlay technology of data is mainly based on life consumption, social network and digital map, which has strong entertainment and interaction. Thirdly, the acceleration of urbanization makes the urban environment worse and worse, for spatial visualization, the combination of visualization technology and GIS technology is also commonly used. For example, the visualization of noise map data often combines with GIS technology to display regional noise distribution by preset color.

2.4. Basic Model and Framework Of Urban Planning Based on Big Data Visualization

2.4.1. Visual Analysis Model. Visualization analysis is a typical cross-cutting research field, which involves human-computer interaction, data analysis, information visualization, etc. [6,21]. The visual analysis model is shown in Figure 1. Firstly, the data are processed and the available data are sorted and stored in the database. Then, the data processed in the database are mapped to the appropriate visualization structure. Finally, the results obtained above are transformed reasonably and displayed on the user interface. If there is unreasonable design or data, the system can be feedback, so that repeated modification and display can achieve the purpose of visual analysis [19].

![Figure 1. Visual analysis model](Image)

The final result of visual analysis is presented to the general audience, so human-computer interaction is an important means for the system and users to collaborate well, providing a clear goal for visual analysis. Urban physical space and human phenomena from different perspectives will show different structural characteristics. To recognize and understand the real environment according to application needs can not be separated from interactive visual analysis operation [22].
2.4.2. *Mobile Data Visualization Framework Based on Urban Planning*

![Figure 2](image1)

**Figure 2.** Main methodological framework for mobile data visualization

Figure 2 is the logical relationship and process of three means of mobile data visualization summarized by Andrienko et al. [23]. The direct description method only needs to display the processed data directly, and does not need too complex summary. When the complexity of the data is difficult to express directly, the summary analysis method presents it to the user after calculation, and explains the data in more steps, which reduces the cost of understanding. On the basis of summary and analysis, feature extraction can be further abstracted to extract data implicit features for analysis. Therefore, visualization requires us to combine various methods to fully understand the data and get the desired conclusions.

3. *Application of Urban Planning Based on Visualization of Big Data*

3.1. *Urban Planning Application Based on Big Traffic Data*

This section introduces a path zooming visualization technology, which can seamlessly embed spatio-temporal information into the map, thus realizing the occlusion-free visualization of spatio-temporal data [24]. The application of route zooming technology in interactive metro map and illustrative map of urban tourism demonstrates the availability of its visualization method.

Figure 3 is a process of creating an occlusion-free visualization system for spatiotemporal data. The core problem is road network optimization and cascade display. In road network optimization, the path scaling problem is transformed into a non-linear least squares optimization problem based on a set of well-defined energy functions with optimization constraints. In the cascade display section, users can interact with the system and overlay various information onto widened routes.

![Figure 3](image2)

**Figure 3.** System creation process and core issues
Fig. 4a is a complex Metro Line in Tokyo, Japan. There is a widened line of the best line that people pay attention to, the information that keeps its own line includes the relevant scenic spots on the line. Figure 4b illustrates the results of traffic simulation around intersections, expanding the connection and putting the results on the road without blocking or distorting context information. Figure 4c shows the same road intersection with wider connecting roads to show a density map with bidirectional traffic flow information. If this technology is not used to cover the density map and rich information on small, undistorted roads, it may lead to congestion.

![Figure 4](image1.png)

**Figure 4.** Example Focus + Context Unobstructed Visualization of Route Scaling Method

Based on path zooming technology, a user-selected focus path is expanded with minimize distorted maps, and spatiotemporal data is analyzed and represented as an inseparable whole. For widening the route and observing the outline map to view the whole to track its interesting scenes, find problems, solve problems can create a better urban travel environment.

In Cadna/A3.7XL noise software, vector data of buildings and roads, accuracy of GIS data, coordinate system and other data are input, and then the results of noise simulation after the introduction of traffic flow data and measured values are shown in Fig. 5. The sound level and noise map of the area are obtained by calculating the noise and sound field distribution of the measured points. The red acceptance mark in the figure indicates that the noise of the point exceeds the standard, while the black one indicates that the noise of the point does not exceed the standard.

![Figure 5](image2.png)

**Figure 5.** Noise simulation effect

The software of GIS platform not only imports the noise simulated map data from Cadna/A software, but also imports the location of the receiving point and the measured environmental noise data. The noise map obtained is shown in figure 6. From the graph, we can see more intuitively the location and attribute information of roads, buildings, etc. The corresponding LAeq values are marked by noise measurement points and contours.
The combination of noise data and GIS platform not only increases the amount of noise map information, but also improves the readability, which provides a good data source for urban noise management.

4. Prospects for future development

At present, data visualization is widely used in urban planning, with the rapid development and transformation of cities, visualization technology still needs to be perfected.

Firstly, simple graphics and images can not meet the needs of big data mining and application, and the complex management and decision-making in urban planning can not be fully and effectively supported, so the relevant practice is still in urgent need of scientific theoretical guidance. Secondly, the development of big data is massive and multidimensional, and the dimension of visualization is limited. We need to extract the most valuable content from it and express it in the most appropriate rendering way, which is the basis for the application of large scale data visualization. Thirdly, data itself does not produce knowledge, but only in specific contexts does it have specific meanings. Large scale data has the characteristics of low value density, so it is necessary to improve the business semantic model to support big data visualization application in all directions and at multiple levels. Finally, the key bridge role of urban planning is human-computer interaction. With visualization as the carrier, the interaction between users and computers and the communication between multi-agents are increased, which is the key to effective and rational decision-making.

5. Conclusion

With the complexity increasing of urban functional system, from traffic trip to logistics and communication, from noise management to ecological balance, from medical and social security to business activities, the multi-detail and multi-dimensional big data in different fields bring opportunities and challenges to the city at the same time. So that the traditional urban planning method based on theoretical knowledge and guided by historical experience can not meet the needs of the current urban planning. But the emergence of big data analysis and visualization provides a new method for modern urban planning. As an effective and flexible means of communication and information expression, visualization not only provides an effective way to explore and analyze large data, but also provides more accurate and intuitive data, cognitive process understanding and problem discovery and solution for urban planning. It is an indispensable part of building a better intelligent city.

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