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Exploring the Application of Big Data Visualization Platform in Urban Traffic Data Analysis

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Abstract: With the rapid development of information technology and the popularity of the Internet, the era of big data has come. The urban traffic system continuously generates a large amount of traffic data, which are so large and diverse that the traditional data processing methods have been unable to effectively process and analyze them. Therefore, it is necessary to process and analyze urban traffic data with the help of emerging big data technologies and methods. Starting from introducing the characteristics of big data visualization platforms and common big data visualization tools and technologies, the article analyzes the scale and characteristics of urban traffic data and the limitations of traditional data analysis methods, discusses the advantages and application prospects of visualization platforms, and focuses on the four perspectives of data cleaning and pre-processing, traffic flow and congestion analysis, traffic behavior and trend analysis, traffic simulation, and planning support. The application of big data visualization platforms in urban traffic data analysis is discussed.

Keywords: big data; visualization platform; urban traffic; data analysis

Introduction

From the perspective of application prospects, visualization platforms have a wide range of application prospects in various fields, especially in big data analysis, business intelligence, scientific research, and decision support. With the growing scale of data and the continuous development of data processing technology, visualization platforms will play an increasingly important role. The advantages of visualization platforms are to provide intuitive data presentation, support interactive data exploration, integrate multiple sources of data, and enable real-time data updates. In the field of urban transportation, visualization platforms can help traffic management departments better understand traffic conditions, plan traffic networks, optimize routes, and provide real-time decision support. At the same time, the interactive functions provided by the visualization platform enable users to interactively explore the data and also provide traffic information services to the public, enabling users to make travel decisions based on real-time data.

1. Analysis of technologies related to big data visualization

1.1 Characteristics of the visualization platform

Big data visualization platform has many unique features and functions, it has data interactivity, and users can interact with the data, explore deeply and discover hidden patterns. The platform also supports multi-dimensional data presentation and can handle and display many types of data. Whether it is structured data or unstructured data, the platform can provide comprehensive display and analysis. By comprehensively displaying the relationships of different data dimensions, users can understand the inherent structure and characteristics of data more comprehensively. This multi-dimensional data display function provides a deeper and more comprehensive perspective for urban traffic data analysis. Real-time and instantaneous enable the platform to process large-scale data and generate updated visualization results quickly to get the latest data insights promptly. Diverse visualizations and chart types enable users to

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choose the presentation that fits their data and analysis goals. The platform also integrates with data analysis and modeling tools to combine visualization results with statistical analysis, machine learning, and predictive models to enable deep data exploration (Liu, & Zhu, 2023). User-friendliness makes the platform easy to use and understand for non-expert users through an intuitive interface and operation.

1.2 Common big data visualization tools and Techniques

Big data visualization tools and technologies have their own advantages and usage scenarios, and the choice depends on factors such as data size, analysis needs, user skill level, and budget. Some of the more common tools include Tableau, the Python Data Visualization Library, and D3.js. Tableau is a powerful visualization tool that makes it easy to connect and manipulate large-scale data and generate interactive and dynamic visualizations. It provides rich chart types, dashboards and storyboards, and other features that allow users to perform data analysis and visualization design through a drag-and-drop interface (Yang, 2023). And there are several powerful data visualization libraries in Python, such as Matplotlib, Seaborn, and Plotly. These libraries provide rich graphing and visualization options and can be seamlessly integrated with other data processing and analysis libraries such as Pandas and NumPy to facilitate data pre-processing and analysis. Unlike the first two technologies, D3.js is a JavaScript-based data visualization library that provides rich visualization components and interaction techniques to create highly customizable visualizations with flexibility. d3.js can directly manipulate the Document Object Model (DOM) to bind data to web page elements and enable dynamic updates and interactive operations.

2. Requirements and challenges of urban traffic data analysis

2.1 Scale and Characteristics of urban traffic data

The scale of urban traffic data is huge, and it records various data describing the operation of urban traffic, including vehicle speed, road congestion, traffic accident statistics, bus and subway operation, and so on. These data are often generated continuously in the form of every second, every minute, or every hour, making the volume of data grow exponentially. Because of this, urban traffic data has a spatiotemporal character, involving not only different periods but also different locations (Yang , 2022). For example, traffic congestion can be different during the morning peak and evening peak, and traffic flow can vary in different areas. Therefore, the analysis of urban traffic data needs to consider both temporal and spatial dimensions to reveal traffic patterns and trends. In addition, urban traffic data has diverse attribute information. Traffic data covers many aspects of information, including vehicle type, speed, lane occupancy, accident time, roadway speed limit, and so on. By analyzing this attribute information, the causes of traffic congestion, the distribution of vehicle flow, the frequency and severity of traffic accidents, etc. can be understood, thus providing data-based traffic planning and management decisions.

2.2 Limitations of traditional data analysis methods

Since the scale of urban traffic data is huge and contains a large amount of temporal, spatial, and attribute information, traditional methods often face challenges in storage, calculation, and processing speed when processing and analyzing these data. Suppose there is a copy of vehicle speed data containing various traffic sections in the city, which is updated once every second. If traditional methods are used for analysis, they may face the problem of insufficient data storage and computational capacity, resulting in limited accuracy and real-time analysis results (Wang, 2023). In addition, traditional data analysis methods often present results in the form of tables and statistical charts, which lack intuitiveness and visualization, resulting in the inability of decision-makers and researchers to gain deep insight into the data, and make a comprehensive understanding of large-scale urban traffic data and discovering potential patterns and correlations becomes difficult. For example, decision-makers would like to identify congested road segments during peak periods from urban traffic data and find the causes of congestion. Traditional methods may only

provide data tables or simple bar charts of congested road sections, but cannot visualize the spatial distribution of congestion levels on road sections and show the correlation between congestion causes and other factors (e.g. weather, time of day, etc.).

2.3 Advantages and application prospects of visualization platform

The biggest advantage of the visualization platform is its intuitiveness, which can help non-specialized users understand the data quickly and assist decision-makers in identifying problems from the data. Through charts, graphs, and maps, the visualization platform intuitively presents data For example, maps show information such as traffic flow, congestion, and accident hotspots, allowing users to visualize traffic conditions in various areas of the city. In addition, the visualization platform can process and update data in real-time or near real-time, which provides users with the opportunity to stay up-to-date on the latest data developments. For decision-makers, this real-time nature allows them to respond and take action faster. For example, in urban traffic management, visualization platforms can monitor traffic flow, congestion, and traffic events in real-time, enabling traffic management to quickly dispatch resources and optimize traffic operations. By intuitively presenting data, the visualization platform enables users to better understand and interpret the data. This visualization not only helps non-expert users to quickly grasp the meaning of the data but also enables decision-makers to identify potential problems and pain points. These problems and pain points may be hidden patterns, anomalies, or correlations in the massive data, and through the visualization platform, they can be highlighted visually to help decision-makers make better decisions.

3. Application of big data visualization platform in urban traffic data analysis

3.1 Data cleaning and pre-processing

In urban traffic data analysis, data cleaning and pre-processing are very crucial steps, which lay a reliable data foundation for the subsequent data analysis and visualization. Urban traffic data often contains a large amount of noise, missing values, outliers, and duplicate data. Just like some vehicles may have outliers due to sensor failures or data transmission problems, recording speeds that are outside the reasonable range. The visualization platform can help identify and deal with these problems through data cleaning and outlier detection techniques to improve the data quality and make the subsequent analysis and visualization result more accurate and credible (Liang, & Zou , 2020). In addition to the case of recording incorrect data, traffic data also often suffer from missing data, which may be due to sensor failures, network problems, or human errors. For example, vehicle speed data for certain traffic sections may be missing due to equipment failure. The visualization platform can provide methods to handle missing values, fill in missing values or use interpolation methods to estimate missing values to ensure data integrity and continuity, making the data analysis and visualization results more complete. After improving the data, urban traffic data often comes from different data sources and different data formats, such as vehicle location data from traffic management departments, weather data from weather bureaus, and real-time traffic information from public social media. The visualization platform will pre-process the data, convert the data formats and integrate them to unify the data from different sources into one format for better analysis and visualization.

3.2 Traffic Flow and congestion analysis

In terms of traffic flow, through real-time traffic flow monitoring, the platform can provide vehicle flow data of various traffic sections in the city to help traffic management departments and drivers understand traffic conditions in real time and make corresponding decisions. For example, the platform can display the vehicle density and speed information of road sections intuitively on the map, helping traffic management departments to take timely measures to guide the traffic flow (Guo , et al.,2021). In addition, the big data visualization platform is also able to analyze and identify congestion hotspots in the city. By visualizing congestion data, traffic management departments can more accurately determine the causes

and influencing factors of congestion and develop corresponding mitigation measures. For example, the platform can identify congestion hotspots, such as intersections and highway exits, to help traffic management departments focus on and carry out traffic signal optimization or road reconstruction. On top of that, the platform will compare data from different traffic modes and visualize them, for example, the platform can compare the travel volume, travel time, and travel distance of public transportation, private cars, and bicycles. This will enable decision-makers to clearly understand the usage and changing trends of various transportation modes, assess the convenience and sustainability of various transportation modes, and thus promote the development of reasonable travel modes to improve traffic efficiency and reduce congestion.

3.3Traffic Behavior and trend analysis

The big data visualization platform can provide powerful support for traffic planning, traffic safety, and travel policies. Through the analysis of urban traffic behavior, the visualization platform can help traffic management departments to understand driving behavior, traffic violations, and traffic safety issues. For example, by displaying vehicle speed and traffic density data in the form of heat maps on a map, traffic management departments can quickly identify areas where dangerous driving behavior is frequent and take corresponding traffic safety measures. At the same time, the big data visualization platform can also analyze the trend of urban traffic and predict the change in traffic flow, the trend of traffic congestion, and the transformation of traffic patterns. By comparing historical traffic data with other relevant data, traffic management departments can understand the growing trend of traffic flow, predict future traffic congestion, and expand roads or improve traffic facilities accordingly (Li, et al., 2023) . In addition, the visualization platform can analyze the usage and trends of different travel modes and provide a basis for assessing the convenience and sustainability of travel modes. By comparing and displaying the data of different travel modes, policymakers can understand the popularity of different travel modes and thus develop policy measures to encourage sustainable transportation modes.

3.4Traffic simulation and planning support

The operation of urban traffic, such as traffic flow, traffic signal control, road congestion, etc., can be simulated through the big data visualization platform to simulate the operation of urban traffic and display the simulation results. For example, different traffic scenarios are simulated, such as traffic flow peaks at specific periods and traffic conditions when traffic accidents occur (Yu, et al., 2022). This result can provide an evaluation of different traffic strategies and measures, prompting traffic planners and decision makers to better understand the evaluation of different traffic strategies and measures in the transportation system and helping decision makers to develop more effective traffic management strategies. For transportation planning support, the big data visualization platform can provide urban transportation planning including new road construction, transportation hub planning, and public transportation network design. The visualization platform can compare data and simulation results of different transportation planning scenarios and present them in the form of graphs or maps. This allows decision-makers to visualize the advantages and disadvantages of different scenarios and helps them evaluate the feasibility and effectiveness of the scenarios to make the optimal choice to improve the urban transportation system. Besides, the visualization platform is also very helpful for traffic demand forecasting. Based on historical traffic data and other related data, the platform can predict future traffic demand changes, such as traffic peaks at specific periods, traffic congestion in specific areas, etc., which provides an important reference for traffic planners to optimize traffic planning, allocate resources and provide more effective traffic services to meet future traffic demands.

Conclusion

In summary, with the increasing scale of urban traffic data, traditional data analysis methods have become difficult to meet the demand for rapid processing and in-depth analysis of large-scale data.

The big data visualization platform adds to the analysis of urban traffic data by helping users understand complex traffic data through intuitive visualization and providing decision-makers with insights and trends to support decision-making in urban traffic management and planning. Its unique features and advantages allow it to handle large-scale data, enable real-time updates, support multi-dimensional data presentation, and integrate with data analysis tools to meet the needs of different users. With the Big Data visualization platform, we can analyze huge and complex traffic data based on easy-to-understand and analyze visual graphs and charts, improve traffic conditions, enhance urban transportation efficiency, and create a more convenient, safe, and sustainable urban transportation environment for people.

Conflict of Interest

The authors declare that they have no conflicts of interest to this work.

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