Analysis and Design of Urban Traffic Congestion in Urban Intelligent Transportation System Based on Big Data and Internet of Things

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ABSTRACT

With the rapid development of big cities, the pressure of traffic congestion is increasing, and intelligent transportation is the fundamental way to solve traffic problems. Intelligent transportation system is a transportation management system that effectively integrates information technology, data communication technology, sensor technology, control technology and data processing technology. Large-scale traffic data management, integration and mining are key technologies. This paper briefly introduces the current situation of intelligent transportation in various countries, analyses the causes of urban traffic congestion in detail, and discusses the concept, composition and relationship between various subsystems of urban intelligent transportation system. Using the Internet of Things technology to collect traffic big data, based on the Big Data analysis technology to construct a traffic prediction model for traffic situation prediction, combined with real-time monitoring and analysis, the combination of remote traffic indicator control and optimization strategy control for traffic collaborative management. The causes of traffic congestion are analyzed in detail, specific solutions are proposed, and suggestions for transportation infrastructure planning are proposed.

CCS CONCEPTS

• **Applied computing ~ Transportation** • Networks ~ Traffic engineering algorithms

KEYWORDS

Intelligent Transportation System, Big Data, Internet of Things, Traffic Congestion

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1 Introduction

With the acceleration of urban modernization, the number of car ownership in major cities has increased dramatically in recent years. Traffic congestion, traffic pollution has become increasingly serious, and traffic accidents have occurred frequently. These have become traffic management problems that need to be solved in major cities. In response to the increasing traffic demand and the pressure of transportation resources, the traditional way of traffic management seems to be inadequate. Intelligent transportation system (ITS) has become an important way to improve traffic management. By use of modern information technology, based on Big Data (BD) and Internet of Things (IoT) technology, the traditional road traffic management methods are deeply reformed to improve the efficiency of urban traffic network and ease urban traffic. Problems and reduce unnecessary losses and improve the efficiency of public transportation [1].

Internet of Things and Big Data technologies help solve urban traffic congestion. The Internet of Things connects various objects according to the agreed communication protocol through various information sensing devices and systems (sensor networks, radio frequency identification systems, infrared sensors, laser scanners, etc.), global positioning systems, etc. Various access networks and the Internet exchange information to realize an intelligent information network for intelligent identification, location, tracking, monitoring and management. It uses the Internet and wireless communication technology to transmit business data. It is a comprehensive display of automation control, remote telemetry and information application technology. The real-time traffic of road vehicles is detected by sensors such as magnetic, RFID and GPS; the real-time vehicle speed is monitored by sensors such as radar; and traffic accident events are monitored in real time through video sensor screens. Through the Internet of Things perception layer, the basic factors affecting the smoothness of urban roads are obtained: people, vehicles, roads, environment and other related data information. Through the analysis and processing of Big Data, traffic management can be assisted to develop a better overall planning and coordination solution. Accurately refining the data and constructing a suitable traffic prediction model can effectively simulate the future operation status of the traffic and verify the feasibility of the technical solution. In the real-time traffic forecasting field, the rapid information processing capability of Big Data has a very high reliability for real-time predictions such as traffic accidents and traffic congestion state detection [2].

2 Causes of Urban Traffic Congestion

2.1 Rapid Urban Development Increases Population and Vehicles in Large Cities

In many big cities, population expansion and the surge of private cars and vehicles are one of the main causes of traffic congestion. There are the following reasons: the distribution of population work and residence is not reasonable, the population density is too large in some areas; in urban public transportation, the investment of public transportation vehicles is also increasing; the increase of non-motor vehicles and pedestrians has a certain impact on traffic congestion [3].

2.2 Unreasonable Planning and Construction of Urban Road Infrastructure

In some large cities, the width of many traffic roads is limited due to land shortages. Due to urban planning problems, the distance between some adjacent traffic intersections is relatively short. There are also traffic lights at the intersection of the bus stop and the number of buses stopping at the bus stop. The switching frequency of the traffic signal and the duration of the red and green lights in a certain direction are long. Another problem that cannot be ignored is that the entrances to schools and hospitals are relatively close to the traffic roads. These situations can all lead to traffic congestion [4].

In Figure 1 below, it is analyzed that traffic congestion maybe happens due to unreasonable traffic facilities.

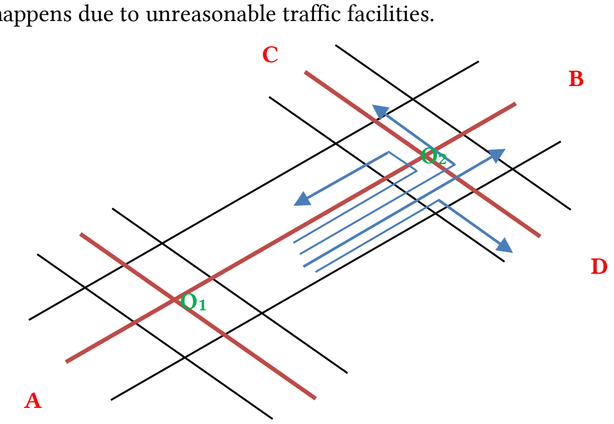

Figure 1: Factors affecting the passage of traffic at traffic intersections.

In the figure: the road is between the black lines, the orange line is the middle of the road, and the blue line with the arrow is the direction of the vehicle. AB and CD represent roads. O1 and O2 are the centres of two traffic intersections. Factors affecting the efficiency of the traffic intersection: the width of the AB unilateral road; the distance between O1 and O2; the direction of the turning of the vehicle at the O2 intersection; the switching frequency of the O2 traffic signal; The time of the red light (or green light) in a certain direction of O2; the conflict between the right turning vehicles and the straight non-motorized vehicles and pedestrians at the O2 intersection.

2.3 Other Reasons Cause Traffic Congestion

Traffic accidents can also lead to traffic congestion. The degree of congestion is closely related to the number and severity of road traffic accidents and the speed of accident handling. The occurrence of major events or events in the city and the necessary traffic control are also one of the causes of traffic congestion. In addition, traffic lights, such as accidental power outages, road construction, bad weather (such as: heavy rain, blizzard, typhoon, etc.). Sometimes, the traffic congestion in the city has some regularity. For example, the commuting time is more likely to cause congestion. Traffic congestion has a certain relationship with the season. In northern China, due to the cold weather, the number of vehicles and pedestrians traveling in winter is less than in summer, and the traffic conditions in winter are better.

In many large cities in China, sharing bicycles facilitates people's travel. The subway has alleviated the traffic congestion pressure of the city to a certain extent, but it also brings certain problems. The traffic congestion near the subway station is very serious [5].

3 Analysis and Comparison of Characteristics of ITS in Major Countries

Generally, in order to solve the traffic congestion problem, urban intelligent transportation mainly uses traffic data to analyze and calculate road conditions, large-scale vehicle path planning, intelligent traffic scheduling, and vehicle diagnosis calculation based on huge cases. The following is a brief introduction to the construction of urban intelligent transportation in major countries in the world.

3.1 Development of ITS in the US

In March 1995, the US Department of Transportation published the “National Intelligent Transportation System Project Planning”, which clearly defined seven areas of intelligent transportation systems and 29 user service functions. Seven major areas include travel and traffic management systems and travel demand management systems. , public transportation operating systems, commercial vehicle operating systems, electronic toll collection systems, emergency management systems, advanced vehicle control and security systems.

According to reports, the current application of ITS in the United States has reached more than 80%, and related products are also more advanced. US ITS is used in vehicle safety systems (51%), electronic tolls (37%), road and vehicle management systems (28%), navigation and positioning systems (20%), and commercial vehicle management systems (14%) The aspect has developed rapidly.

3.2 Unreasonable Planning and Construction of Urban Road Infrastructure

At present, Europe is undergoing full development of Telematic. It plans to establish a dedicated wireless data communication network (based on road traffic) throughout Europe. It is developing an advanced travel information service system (ATIS) and advanced vehicle control system (AVCS). , advanced commercial vehicle operating system (ACVO), advanced electronic toll collection system, etc.

In 2015, European countries carried out Telemetric's comprehensive application development work, and planned to establish a dedicated traffic wireless data communication network throughout Europe. It plans to establish a dedicated wireless data communication network (based on road traffic) throughout Europe, and is developing an advanced travel information service system (ATIS), advanced vehicle control system (AVCS), and advanced commercial vehicle operation system (ACVO)., advanced electronic toll collection system, etc.

At present, the intelligent transportation department in Europe is at the international advanced level. So far, a considerable part of research results has been put into practical application. The development and application of EU intelligent transportation system technology is based on the current status and development goals of EU transportation, making full use of existing information and communication technologies (ICT), computer and Internet technologies, satellite navigation technology, electronics and sensor technology, and energy saving. Row and new propeller technology. Cross-integration and optimal configuration of technologies to achieve a more efficient, safer, cleaner and more punctual approach to passenger and cargo transportation.

The European Commission adopted the "European cooperative intelligent transportation system strategy" on November 30. The goal is to deploy a cooperative intelligent transportation system on the roads of EU countries by 2019 to realize the relationship between cars and cars, between cars and road facilities. "Smart communication."

ERTICO, the European ITS organization, proposed e-Safety's basic concept eSafety70 for various R&D projects, all of which focused on vehicle communication and collaborative control [7].

3.3 Development of ITS in Japan

The Japanese ITS planning system includes advanced navigation systems, safety assistance systems, traffic management optimization systems, road traffic management efficiency systems, bus support systems, vehicle operation management systems, pedestrian guidance systems, and emergency vehicle support systems. Japan's ITS is mainly used in transportation information provision, electronic toll collection, public transportation, commercial vehicle management, and emergency vehicle priority. There are currently more than 18 million car navigation system users in Japan.

There are more than 12 million vehicles equipped with car navigation systems in Japan, and more than 7 million vehicles are equipped with car navigation systems and VICS receivers. The above devices can be drivers or other vehicles. The user provides instant road information. Therefore, there are many road cars in Japan without chaos. Many monitors and radars on the road monitor road conditions and collect information at any time, and drivers can obtain instant road information through the information board. Car electronic maps have been widely used.

Japan's ITS program has completed the fourth phase of the "Advanced Safety Vehicle" (ASV) project, which has basically entered the stage of practical technology development. The vehicle-road coordination system developed by it has formed mature products and a huge industry [8].

3.4 Development of ITS in China

In China, the research and promotion of intelligent transportation systems is still in its infancy, and has been highly valued by relevant state departments, highlighting the status of intelligent transportation of the Internet of Things. At present, in the field of urban intelligent transportation, the construction of intelligent transportation system in Beijing has achieved initial results, mainly in the following six aspects: (1) Road traffic management: a relatively complete intelligent road traffic command management system, including urban road traffic, has been built. Signal control system, traffic detection, TV monitoring system, traffic violation detection system, etc. (2) Public transportation management: the bus hub operation management and passenger information service system, bus area operation organization and dispatch system, bus repair and rescue dispatch system, BRT intelligent management system (3) travel information service: self-developed floating car dynamics The traffic information collection, processing and distribution system effectively expands the scope of dynamic traffic information collection. (4) Electronic charging: The municipal traffic card system was opened in the city's public electric cars, rail transit and all taxis; (5) GPS monitoring system for transport vehicles; (6) completed traffic operation coordination command centre and road network operation and transportation supervision The three sub-centres of public transportation security form an integrated and intelligent comprehensive traffic command support system, which becomes the data sharing exchange centre, the integrated transportation coordination operation centre, the information release centre, and the traffic safety emergency command centre in case of emergency.

The public will be able to grasp the road condition information in real time through websites, hotlines, mobile phones, car navigation and other forms, and arrange travel in advance. At the same time, bicycle rentals also implement networked services.

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4 Research on Big Data and Internet of Things technology in Intelligent Transportation System

Generally, Among the factors affecting traffic congestion, the collected traffic data is divided into static data and dynamic operational data [10]. Static data refers to long-term fixed data, such as the width of traffic roads, the setting of traffic intersection signals, the lane setting of roads, the distance of adjacent intersections, and so on. Dynamic operational data refers to data that changes in time in traffic information data, such as: location information of vehicles, number of pedestrians at traffic intersections, number of motor vehicles at traffic intersections, and so on [12]. In the case of legal permission and protection of personal privacy, the location information is obtained by the GPS positioning system, the location information of the vehicle or pedestrian is obtained, and the movement trajectory is predicted [13].

Through the Internet of Things remote terminal equipment, collect traffic information and transmit it to the Big Data centre, establish a dedicated storage system, analyse, classify, organize, and make decisions and implement control [14,15]. First of all, the electronic map library is the basis of the intelligent traffic control system. It must be first established and updated in real time to provide guarantee for the accuracy of GPS navigation. Road information, traffic flow information, vehicle status information, and parking space information must ensure real-time performance to ensure traffic. Scheduling accuracy and security [16,17].

Big Data uses road information and human travel information for analysis. Big Data technology greatly reduces the requirements for the structure of data [18]. It uses real-time processing of information such as road information, behavioral habits, and preference information of pedestrians to outline various characteristics of each individual to discover a large amount of traffic flow information. Implicit patterns and rules. Big Data will be dispersed in different departments of traffic data, such as personal information, public transport network information, logistics information, weather information and other information related to the traffic related departments, so that the information of all departments is open and interoperable, to achieve multi-level, cross-sectorial Information resource exchange and sharing. The collaborative computing of heterogeneous data is to enhance the knowledge discovery ability, not only to solve the problem of information fusion, but also to solve the cross-domain association problem of multi-source data [19,20].

4.1 Intelligent Transportation System Structure based on Big Data and Internet of Things

System architecture discusses the use of the bottom layer of the Internet of Things perception layer to obtain data, the network layer to collect data, Big Data technology data pre-processing, cloud computing platform to provide computing services, large data analysis, and finally to the Internet of Things upper application layer. By use of large data analysis, using historical data and real-time data to predict traffic congestion, remote control traffic lights. According to the corresponding strategy, traffic signal switching frequency or delay the green light time in the direction of congestion are carried out for single intersection congestion. For multi-intersection congestion, multi-intersection signal coordination is used to smooth traffic congestion [21,22,23].

The hierarchical structure of the system is analysed in detail (see Figure 2).

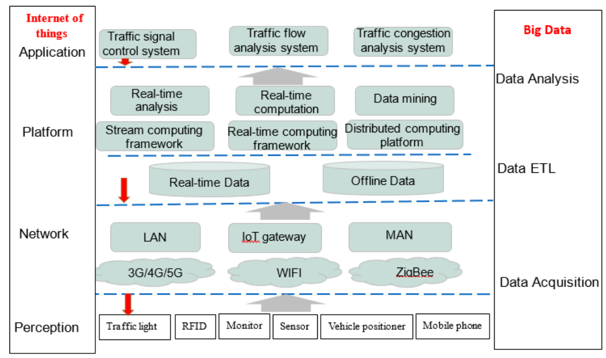

Figure 2: ITS architecture based on Big Data and internet of things

4.2 Traffic Data Acquisition and Pre-processing

Through the sensing layer of the Internet of Things, a series of data acquisition devices, such as mobile phones, car networking, GPS, video surveillance, cameras, etc., obtain a series of information such as the time, location, and number of the traffic vehicle. The purpose of obtaining this information is to analyse the vehicle's trajectory and predict the amount of traffic and the likelihood of congestion in a place [24,25]. The information in Table 1 below is required and how to obtain the information.

Table 1: Vehicle information on traffic roads.

Items	Data Sources	Description
Buses	Time, Location information, Car number	Internet of Vehicles, GPS,etc.
Taxis	Time, Location information, Car number	Internet of Vehicles, GPS,etc.
Private cars	Time, Location information, Car number	GPS,etc.
Logistics vehicles	Time, Location information, Car number	Internet of Vehicles, GPS,etc.
Other vehicles	Time, Location information, Car number	GPS,etc.

Logistics-related vehicles include oil tank trucks, cement tank trucks, garbage collectors, trucks with detachable decks, car carriers, and water sprinklers etc.

Pedestrians and non-motorized vehicles are an important factor affecting traffic congestion in some large cities. Pedestrians and non-motorized vehicles are an important factor affecting traffic congestion in some large cities. Especially at some traffic intersections, pedestrians or non-motorized vehicles who do not obey the traffic rules affect normal driving, which is likely to cause traffic congestion [26,27]. Due to improper setting of traffic lights at some traffic intersections, turning vehicles will also collide with pedestrians and non-motorized vehicles, causing traffic accidents and causing traffic congestion. The information in Table 2 is about the data of the Pedestrians and non-motorized vehicles. In China, motorcycles are driven on non-motorized roads. The subway has slowed down the pressure on the ground traffic, but the subway station is a place that is likely to cause traffic congestion. Non-motor vehicles are divided into bicycles, tricycles, electric bicycles, disabled motor wheelchairs and animal vehicles [28].

Table 2: Pedestrians and non-motor vehicles information on traffic roads.

Items	Data Sources	Description
Pedestrians	Time ,Location information	Bus card, Mobile phone GPS, etc.
Non-motor vehicles	Time ,Location information	Mobile phone GPS
Motorcycles	Time ,Location information	Mobile phone GPS
Other auxiliary public transport	Number of passengers transported by subway	Bus card, Mobile phone GPS, Ticket sales, etc.

The condition of roads is also a factor affecting traffic. Traffic will be good with the more lanes, the wider lane, and the longer distance of adjacent intersection and the higher of the lane. The contents in Table 3 detail this aspect.

Table 3: Road conditions related to traffic congestion.

Items	Data Sources	Description
Number of lanes	Quantity	Lanes of the road
Lane width	width	The wider the better
Adjacent intersection distance	length	The long the better
Speed limit	Quantity	Usually 60 or 40

There are many other complex issues that affect the state of urban road traffic. It not only includes the differential impacts of different regions of the city, including differences in population density in different regions of the city, differences in road infrastructure construction specifications, etc., but also due to environmental factors such as weather, for example heavy rain, blizzard and other abnormal weather. There are other factors that affect traffic congestion: the occurrence of major events, traffic flow control, and maintenance of transportation facilities [29]. The information in Table 4 below is descript in detail.

Table 4: Other factors affects traffic congestion.

Items	Data Sources	Description
Weather	Abnormal weather	Heavy rain, strong winds, heavy snow, etc.
Important event	Sports competitions, foreign leaders visiting, etc.	Pay attention to news information
Traffic control	Traffic accident limit	
Traffic maintenance	Road repair, bridge repair, etc.	

4.3 Data Analysis and Processing

Based on the analysis of dynamic traffic flow and road network congestion status, combined with the temporal and spatial characteristics of traffic data and traffic domain constraints, the potential similarities, correlations and correlations of the data are analyzed in depth [30]. The traffic data is clustered, predictively analyzed, correlated with analysis, and anomaly detected, so as to discover the knowledge hidden by different feature dimensions and different data granularities, and use the dimensionality reduction technology to process the data.

4.3.1 Short-term intersection traffic flow prediction traffic flow forecast. We combine data flow data and use data mining technology to predict traffic flow. Traffic flow data is a form of time series that is segmented according to changes in time series data characteristics. The most commonly used time series segmentation method is a piecewise linear description, that is, the sequence is segmented and described piece by piece using a linear model. K-Means clustering algorithm is used as the basis of sequence segmentation. The traffic flow is predicted by the combined model algorithm of sequence segmentation and BP neural network. The traffic flow pattern is divided according to the two-dimensional clustering algorithm of flow and time [31,32].

4.3.2 Traffic congestion forecast. Traffic congestion prediction model research belongs to the pattern recognition problem of information science. At present, many research results of traffic congestion prediction are mainly concentrated in the subject area, mainly based on time series correlation prediction analysis, neural network prediction, Bayesian network prediction, and multi-classifier combination prediction [33].

The traffic flow feature vector is constructed by summarizing the basic data such as the traffic flow parameters, the environmental state, and the time period, and the four predicted states are determined (then the levels are determined according to different driving speeds, such as smooth: $V \geq 30$; Crowded: $10 \leq V \leq 30$; Congestion: $3 \leq V \leq 10$; Blockage: $V \leq 3$, V stands for speed and is measured in km / h). A self-encoding network method using deep learning learns from the unlabeled data set to obtain hidden layer parameters that can characterize deep features of the data and generate new feature sets. Softmax regression is used to learn the new feature set with label to generate predictive classifier, and the model predicts the polymorphism of traffic congestion [34].

4.4 Remote Traffic Control

By use of traffic history data and real-time data, traffic data prediction and traffic congestion prediction based on map information are carried out through Big Data analysis. Through the Internet of Things remote control to adjust traffic lights, single or adjacent traffic intersection traffic light control system is regulated according to certain optimization algorithms to carry out traffic diversion and ease the pressure of traffic congestion. The traffic signal control system adopts a three-layer distributed structure, and the system structure is divided into three layers: a signal control centre, a communication part, and an intersection part. The signal control centre equipment mainly includes a central control server, a regional control server, a communication server, a database server, and the like. The communication part mainly includes an optical transceiver and a communication network. Some equipment at the intersection mainly include signal machines, detectors, etc. The signal machine adjusts the intersection control scheme (signal period and green signal ratio) in real time according to the traffic information (including traffic flow, etc.) detected by the vehicle detector to realize the orderly control of the intersection [35].

The central level control mainly completes the management of the whole area and the city-level traffic control functions, including parameter setting, area monitoring, and service control. Regional level control: It mainly completes the traffic information collection, processing, prediction and optimization of the regional signal machine, and delivers the control plan to the intersection [36]. The optimization prediction function of the regional control server is to optimize the strategic level of the intersections in the region, and to optimize the first cycle of the cycle length, green signal ratio and phase difference. The regional control server is also responsible for the control and monitoring of the signals in the area. The intersection level control completes the collection and upload of traffic information, and completes the execution of the central control plan. At the same time, according to the actual traffic demand at the intersection, the green light time should be adjusted in real time on the basis of the optimization of the centre, so that the signal timing can be adapted to the maximum extent of the intersection to achieve the best level of smoothness [37].

The control system has the following functions: yellow flash, full red, single point fixed cycle, single point multi-time period, green wave control, real-time adaptive optimization control, multi-time timing control, bus priority control function, emergency vehicle priority control, forced control, service plan control and other functions. Map-based traffic monitoring can be displayed in regional traffic flow status, monitoring saturation, displaying traffic execution status, monitoring service execution status, monitoring vehicles, displaying intersection release status, monitoring sub-area control status, and monitoring for incidents. For congestion at multiple intersections, multi-channel traffic lights are coordinated to clear traffic congestion [38,39].

5 Conclusion

There are three main ways to solve traffic congestion: controlling demand, that is, reducing the number of vehicles and people; increasing supply, that is, increasing traffic roads and related facilities; and improving the utilization efficiency of transportation facilities. The former two methods do not meet the growing traffic demand. Utilize the Internet of Things and Big Data technology to comprehensively and accurately grasp the traffic information of the entire city, and provide practical data and solutions for traffic guidance and urban planning. Mainly solve the following problems: 1. Traffic congestion prediction analysis and processing; 2. Traffic flow forecast; 3. Provide scientific basis for future transportation facilities construction planning. Use the Internet of Things to collect data, obtain real-time data and historical data, and collect data. Using Big Data technology, the data is cleaned and pre-processed, and the appropriate algorithm is selected to establish a traffic prediction model. Remote control of traffic lights through the Internet of Things to increase traffic flow at traffic intersections. With the widespread use of driverless technology in large cities, intelligent transportation systems based on Big Data and the Internet of Things provide accurate and highly reliable traffic information for the Internet of Vehicles.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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