Research on Big Data Traffic Congestion Analysis and Judgement Platform Technology

Xiaowei Li\textsuperscript{1,a}, Ting Xiong\textsuperscript{2,b}, Mengyan Yu\textsuperscript{3,c,*}

\textsuperscript{1}China Mobile Hubei Co., Ltd. Jingzhou Branch, Jingzhou, Hubei, 434000, China
\textsuperscript{2}Wuhan University of Technology School of Transportation and Logistics Engineering, Wuhan, Hubei 430063, China
\textsuperscript{3}Wuhan University of Technology School of Transportation and Logistics Engineering, Wuhan, Hubei 430063, China

Abstract: Due to the lack of peak intersection congestion coordination control strategy, at present, most of the points during the peak period of the urban area only fixed cycle control, can not sense the downstream intersection queuing length in time, resulting in the downstream congestion is still normal release, so that part of the vehicle into the intersection queue, in the cross-direction before the release of the vehicle traffic, resulting in intersection blockage. In the platform to introduce the peak intersection congestion coordination control strategy to reduce the length of vehicle queues to ease peak congestion, the platform is mainly responsible for congestion analysis, indicator calculation, traffic research and judgement can be found in the real-time environment of the congestion and the formulation of countermeasures to support the signal control, traffic organisation, police scheduling and so on.

1. Introduction

With the growing urbanisation of the city and the rapid increase in the number of motor vehicles, China's car ownership accounted for three per cent of the world, the contradiction between the city's traffic demand and the current traffic management is becoming increasingly obvious, and traffic-related cases are also increasing year by year. In this case, how to further use advanced scientific and technological means to improve the level of traffic management, to improve the road traffic environment is an urgent problem to be solved.

1.1. Key technologies

As a huge, complex and dynamic system, the intelligent transportation system needs to have four core technologies: perceptual intelligence, cognitive intelligence, decision-making intelligence, and organisational intelligence. Perceptual intelligence means that the system platform is able to intelligently perceive the real-time situation of the urban road network through a huge number of perceptual devices in the outfield, and is able to accurately measure and determine the traffic flow status and the network's event dynamics and other key elements with some kind of quantitative index system; cognitive intelligence is that the system is able to judge the events and reasons behind the road network through artificial intelligence algorithms based on the value of indicators. Cognitive intelligence is based on perceptual intelligence, and the system is able to judge the events and reasons behind the events in the road network based on the values of the indicators through artificial intelligence algorithms. Decision intelligence and organisational intelligence are concerned with how the system platform can make optimal responses to various traffic states or events in a real-time environment.

1.2. Causes of Traffic Congestion

The untimely discovery of the source of traffic congestion, the lack of in-depth analysis of the causes of traffic congestion, the lack of clarity on the expansion of the traffic congestion impact law and its dissipation law, the lack of relevance of traffic congestion countermeasure programmes and the lack of a feedback mechanism for evaluating the effectiveness of traffic congestion countermeasures are the main reasons for failing to crack the problem of traffic congestion in a timely and effective manner.

1.3. Status of research

The world's first echelon of the development of intelligent transport systems in the United States, Japan, Europe and other countries and regions\textsuperscript{[1]} , the construction of its intelligent transport system is more complete and advanced. As early as 1996, Japan launched a 20-year plan aimed at easing urban congestion, ITS in the planning of the strong support for the development of a very good, the development of the indicated VICS system\textsuperscript{[2]} . The United States in the
sixties of last century began to try to giant image can only what through the traffic system applied to congestion detection, due to some reasons stalled for about 10 years, after the United States began to pay attention to the problem of traffic congestion[3]. The Intelligent Traffic Control System in Berlin, Germany, is able to predict traffic flow in the short, medium and long term, and is particularly effective in predicting traffic congestion within the next half hour[4]. The traffic management system developed in Canada, which integrates traffic monitoring, detection, control and guidance, has been effective in easing traffic congestion and reducing traffic accidents[5][6].

The research of intelligent transport system in China is later than that of foreign countries, and it has been developed rapidly in recent years in continuous learning. In response to the problem of traffic congestion, in terms of road traffic, the relevant application developed on the basis of big data is an effective technical way to alleviate the traffic pressure in large, medium and small cities[7]. Through the study of traffic-related big data will be conducive to understanding the current situation of urban traffic congestion in people and motor vehicle travelling patterns, discovering the causes of traffic congestion, and formulating solutions, so as to provide protection for the masses to travel, further create livable cities, and provide the government with comprehensive decision-making based on big data as a basis for improving accurate management.

Up to now, more than 400 cities in China have built an intelligent command and control centre integrating information collection, equipment control, traffic command and police reception and handling, and many cities have completed the control of traffic signals or green wave road control. China has already realised the networked disposal of vehicle and driver offence information.

2. Technical Architecture

2.1. Design principles

Massive amounts of data are prone to present a large but disorderly, many but useless situation, the use of big data to enhance the refinement and intelligence of traffic management, the organisation and processing of big data must be systematic and hierarchical. Dynamic data and static data need to be combined, for road network data, equipment data, personnel and vehicle data, event arrangement data and other static data, these data generally do not change with the change of time or change very slowly; while the electric police bayonet data, flow measurement data, real-time track data, etc. is dynamic change, only dynamic, static two kinds of data can be a perfect combination to really play the role of big data. Based on different types of data sources through the anomaly identification, cleaning, repair, fusion and other data processing, the output is more accurate, complete, high-quality intermediate results of the data, multi-source data, heterogeneous data fusion can make up for the shortcomings of a single dataset, from the overall level of the analysis of a full set of traffic indicator data.

Depending on the source of the data, it can be categorised as the traffic police's own data, shared data and Internet data. These three sources of data need to be used in an integrated manner and at the same time need to be treated differently. Among them, the basic disc of big data needs to be data that can be prepared or collected by the traffic police department on its own, and the extended data includes shareable data from external departments and Internet data. First of all, all traffic control big data applications need to be based on the basic disc to ensure the core functions, while the system should have a certain degree of scalability so as to be able to accommodate more diversified data.

2.2. Logical Architecture

The layers of the traffic big data analysis platform are divided into intelligent sensing equipment layer, data access and fusion layer, traffic index calculation layer, congestion analysis and judgement layer and control strategy support layer. The functional realisation of each layer is based on the functional realisation of the following layers.

2.2.1. Intelligent Sensing Device Layer

A collection of software that connects directly to sensing devices in the field (including but not limited to cameras, radar, chokepoints, personal wearables, signal controllers, and edge computing devices) and is responsible for transmitting real-time sensing information from the devices back to the data centre through the development of embedded programs and network protocol programs.

2.2.2. Data management layer

Save all the traffic big data in a specific data storage format and provide management functions for all the traffic big data converged into the data centre. The data management layer includes the data storage infrastructure layer and the traffic data model layer.

2.2.3. Traffic Indicator Calculation Layer

Traffic indicators are broad indicators, not only limited to congestion indicators, but also include traffic police attendance, the scope of search and seizure control, law enforcement results, etc. are part of the indicator system. Traffic indicator system is a quantitative indicator system defined and calculated based on all basic data for all urban traffic management operations. The traffic indicator calculation layer is a collection of procedures to complete the calculation of all traffic indicators.

The traffic flow indicator calculation engine is a program that processes traffic flow indicators in a real-time environment based on perceptual big data and other static data. It is divided into multiple technical routes, and the specific calculation process is shown in Figure 1.
2.2.4. Data analysis and judgement layer

The analysis and judgement layer is the upper application of the index calculation, which is above the index calculation layer, and is a collection of business algorithms and models. The indicator calculation layer can analyse the flow and delay of each direction at an intersection, while the data analysis and judgement layer analyses whether the intersection is congested and the reasons for congestion based on the flow and delay.

2.2.5. Traffic Management Strategy Optimisation Layer

Strategy optimisation is based on all the indicator judgments and research conclusions, with AI intelligent algorithms and expert solution libraries as the means to output countermeasures. Strategies are the countermeasures that can be directly implemented to improve the current traffic state, including traffic organisation strategies, signal control strategies, vehicle navigation strategies, police scheduling strategies, and so on. The traffic management strategy optimisation layer contains all the data and algorithms for generating these countermeasures, and serves as the top layer of the entire traffic big data analysis and judgment platform.

3. Functional Architecture

3.1. Traffic congestion prediction and online identification

Traffic congestion judgement and online identification function module is mainly to monitor the road traffic flow operation status, based on traffic flow theory and artificial intelligence theory and method analysis, according to the traffic volume, speed and density of the law of change rate of real-time judgement prediction of traffic flow status and its changing trend, predict the possibility of traffic congestion, the first time to foretell and the system to get ready. This accurate prediction of the upcoming traffic congestion situation is the key to avoid the formation of large-scale traffic congestion, resulting in serious traffic congestion consequences.

3.1.1. Intersection congestion identification

Intersection is a concentrated area where traffic congestion occurs, and intersection congestion includes normal congestion and non-normal congestion. Normal congestion is predicted by historical data analysis and evaluated by congestion index; non-normal congestion is achieved by calculating the speed change of the inlet lanes of the intersection, combining with the traffic light information to judge the speed change condition at the lane level, and realising the congestion alarm at the second level. Intersection congestion identification is based on the calculated intersection relative congestion index and absolute congestion index, taking into account the time characteristics of congestion, spatial characteristics and congestion characteristics (such as the three parameters of traffic flow, etc.) for the breakdown of congestion dismantling, through the feature extraction and pattern recognition, whether the intersection congestion, congestion, congestion, the nature of the extent of congestion and the characteristics of the intersection (belonging to the constant hair type of congestion or sudden type of congestion) to quantitative analysis and assessment, and can be used to quantify and assess the congestion and congestion. Quantitative analysis and assessment, and presented in the form of visual UI.

3.1.2. Arterial congestion identification

Arterial congestion and intersection congestion is divided into regular congestion and extraordinary congestion, the difference between the two is that the cause of congestion varies greatly, arterial road section regular congestion is mainly for the capacity of the sudden change of the physical bottleneck, the application of on-street parking caused by the reduction in capacity and regular non-motorised traffic illegal concentration of the section caused by; unconventional road section congestion is mainly caused by the occurrence of traffic accidents, abnormal weather such as snow and ice, Unconventional road congestion is mainly caused by traffic accidents, unusual weather conditions such as snow and ice, and random offences by traffic travellers.

3.1.3. Regional congestion identification

There are two main functions of regional congestion identification, function one is to calculate regional average speed, traffic volume, traffic density, congestion queue length, regional relative congestion index, regional absolute congestion index and other regional congestion indicators calculation. Function two is to judge the level of regional congestion by combining multivariate data, judging the possibility of congestion occurrence, the
posture after occurrence, the degree of influence and the analysis of causes of congestion through the comprehensive analysis of regional congestion indicators.

3.2. Analysis and diagnosis of the causes of traffic congestion

The investigation of the causes of congestion is divided into several categories, namely congestion caused by going demand, congestion caused by unexpected events, congestion caused by signal timing and congestion caused by junction channelisation.

After the identification and determination of traffic congestion, the causes of traffic congestion are analysed for different types of congestion, and the diagnosis of the causes of congestion is quantitatively analysed and calculated in congestion prediction and identification, and the analysis and diagnosis of the causes of traffic congestion are based on the characteristics of traffic congestion and the characteristic parameters of the traffic flow, and the temporal and spatial distributions of congestion through the points, lines, and surfaces are comprehensively analysed and judged.

The analysis process of traffic congestion causes is shown in Figure 2:

Fig.2. Flowchart for analysing the causes of congestion

3.3. Forecast of traffic congestion dynamics

The posture prediction of congestion is based on the congestion identification function to map out the existing state of the road network, and then use the propagation speed and path of the congestion queue to dynamically predict the future scope of congestion spread, so as to form an alarm system.

Based on the historical congestion indicators, the system analyses the change pattern, automatically monitors the trend of the system indicators, and forms an alarm mechanism for abnormal changes. Based on the prediction model, it predicts the congestion state in the future time period, and the system forms warning information and countermeasure programmes for congested intersections, road sections and regions according to the prediction results.

The system first calculates the velocity of the congested echoes according to the Rankine-Hugoniot leapfrog condition, involving conservation equations and density-flux curves.

The Rankine-Hugoniot leapfrog condition is used to calculate the velocity of the congested echoes with the conservation equation:

\[
\frac{dQ}{dt} + \frac{dF}{dx} = 0
\]

where \( Q \) is the traffic flow (usually expressed as a number of vehicles or flow units); \( F \) is the volume of traffic flow (usually expressed as one vehicle per hour); \( x \) is the spatial coordinate; \( t \) is time;

Density difference:

\[
\Delta \rho = \rho_2 - \rho_1
\]

Poor flow rate:

\[
\Delta Q = Q_2 - Q_1
\]

Echo Velocity:

\[
v_r = \frac{\Delta Q}{\Delta \rho}
\]

Scope of dissemination:

\[
D_r = v_r \cdot t
\]

Calculate the ratio between the flow difference and Density difference between the congested section and its upstream non-congested section, and then determine the echo speed according to the slope of the chord connecting the two traffic flow state points on the density-flow curve, which is the propagation speed of the congestion wave, and multiply this speed by the time to get the propagation range of the congestion wave at any time. The system will give the prediction of the congestion range and influence degree at any time accordingly. The prediction of congestion situation includes single-point, arterial, and regional congestion prediction, in which the single-point is for a single intersection in all directions of the queue and congestion level prediction, arterial and regional congestion prediction is for a single arterial live traffic area of the future congestion index.

3.4. Congestion analysis and countermeasure generation

The generation of real-time countermeasure scheme is formed on the basis of traffic congestion prediction and analysis of causes of traffic congestion, and in response
to dynamic changes in traffic demand and congestion caused by irrational control schemes, the corresponding area forms a proposal for traffic organisation scheme to eliminate or reduce the impact of congestion through external means. The system puts forward suggestions for re-optimisation of the traffic control scheme in the corresponding area to achieve real-time on-line optimisation of signal control, which is mainly used for road sections and intersections that have already been identified as congested, and takes the congestion characteristics of congested intersections or arterial routes, the causes of congestion, and the relevant information and detector data on traffic infrastructure, traffic demand, signal control, etc., as input data, so as to output the optimised traffic control mode or signal control parameter. Control parameters. Based on the analysed causes of congestion, it automatically proposes a targeted scheme, which can make the scheme adjustment more real-time and intelligent, and even achieve the effect of eliminating congestion by adjusting in advance, and on the other hand, it can avoid the situation that the throughput capacity cannot be improved due to improper manual operation.

In addition, the proposal of traffic organisation optimisation is a comprehensive countermeasure scheme that considers the adjustment of traffic demand from the overall perspective of the regional situation, and consists of a series of traffic organisation management measures and is coordinated with traffic signal control. The predicted traffic demand data, the traffic flow data collected by the detector and the congestion information obtained from congestion identification and cause analysis are used as input data to form a targeted traffic organisation scheme by calculating the traffic flow imbalance degree and other indexes, and finally outputting the characteristic parameters of the traffic flow and the corresponding traffic organisation scheme.

4. Summary

The construction of this intelligent traffic management system starts from the functional requirements of solving traffic congestion, and builds a high-level, strong practical ability, and good practical effect traffic congestion analysis and judgment platform. The platform consists of modules for traffic congestion prediction and online recognition, analysis and diagnosis of traffic congestion causes, generation of congestion countermeasures, and evaluation and tracking of congestion mitigation effects through congestion situation analysis. These advanced functions, as the highlights and innovations of this intelligent traffic management system, are a new breakthrough in commanding the construction of the traffic management system, will significantly improve the intelligent level of traffic management, produce significant investment effects, and reflect the practicality, progressiveness, and forward-looking of the intelligent traffic management system. At the same time, the platform also has shortcomings, among which the quality of data and the reliability of data sources are major challenges. During the data collection process, there may be issues such as missing data, data errors, or unstable data sources, which will affect the accuracy of analysis and prediction. However, with the further development of the Internet of Things and sensor technology, data collection devices will become more intelligent and efficient, providing more accurate and real-time traffic data. In addition, data fusion and cross application with other fields will also bring new breakthroughs to traffic congestion analysis. Finally, the government and enterprises should strengthen cooperation to jointly promote the development of big data traffic congestion analysis and judgment platforms, in order to achieve the goals of transportation intelligence and urban sustainable development.

References