Proceedings of CONF-MLA 2024 Workshop: Mastering the Art of GANs: Unleashing Creativity with Generative Adversarial Networks
DOI: 10.54254/2755-2721/111/2024.CH18112

Short-Term Traffic Flow Prediction: Techniques and Methods

Yitong Ji

HKUST Fok Ying Tung Research Institute, Hong Kong University of Science and Technology, Hong Kong, China

jiyitong0809@gmail.com

Abstract. With the development of the economy, the expansion of the city scale, the increase in the population of urban residents and the increase in the per capita car ownership, the traffic congestion problem has an increasing impact on urban operation. Especially during the peak period of commuting traffic and holidays in large cities, most cities are facing the serious problem of road congestion. In order to facilitate the travel of residents and reduce air pollution, it is very important to keep the main road of the city smooth and rapid passage of vehicles. Therefore, cities should vigorously develop short-time traffic flow prediction, and accurate prediction of short-time traffic flow is the key to realizing intelligent urban traffic operation and efficient traffic flow management improvement. This paper will talk about the time series prediction model of short-time traffic flow prediction methods and advantages and disadvantages to provide auxiliary support for solving the traffic congestion problem, provide efficient travel path decision-making guidance for urban residents, facilitate the saving of urban people's travel costs, and also provide effective police deployment decision-making information for the traffic management department.

Keywords: urban roads, short-term traffic flow, prediction methods.

1. Introduction

With China's rapid economic and social development and the continued acceleration of the pace of urbanization, coupled with the widespread popularity of new modes of transportation such as shared bicycles and online cars, which have had a far-reaching impact on the existing traffic pattern, China's major cities are experiencing a growing imbalance between supply and demand for transportation, and congestion phenomena are becoming more and more frequent and severe test. Especially in the center of the city where there is a lot of traffic and people., the road in the peak hours of commuting and holidays shows obvious tidal characteristics, coupled with a variety of complex factors intertwined, so that part of the road in a specific period of time is seriously congested, the contradiction between the demand for travel and the supply of the more prominent. This social problem not only seriously affects the quality of people's daily lives, leading to a large amount of valuable time travelers waste, but also resulting in huge economic losses, exacerbating the excessive consumption of resources, and the environment caused by pollution can not be ignored. Therefore, finding and implementing effective strategies to reduce traffic congestion has become an important issue. Traditional measures such as expanding roads, implementing traffic restrictions, or restricting the purchase of vehicles can alleviate

DOI: 10.54254/2755-2721/111/2024.CH18112

congestion to a certain extent, but it is difficult to solve the problem fundamentally, and it is even more difficult to adapt to the ever-increasing traffic demand. In this context, exploring innovative methods based on traffic information, such as short-term traffic flow prediction, to provide urban residents with more accurate travel assistance decisions, has become a new direction to alleviating urban traffic congestion [1]. Therefore, exploring effective strategies to alleviate traffic congestion has become an important issue that needs to be tackled. Initial measures, such as road expansion, traffic restrictions (e.g., single- and double-numbering policies), and vehicle purchase restrictions, can reduce congestion to some extent, but fail to address the root of the problem and are difficult to adapt to the growing demand for transportation. In this case, many transportation researchers and managers have shifted their focus to the research and practice of new methods based on traffic information, and the simulation of short-term traffic flow prediction has emerged. Through the short-term traffic flow prediction for urban residents to travel provides better auxiliary decision-making tools, diversion of urban vehicles, to solve the phenomenon of urban traffic vehicle congestion [2]. Short-time traffic flow prediction plays a crucial role in modern urban traffic management, which is the core basis for accurately judging the current traffic situation and scientifically making decisions on travel paths. Unlike macro forecasts that often use weekly, monthly, yearly and other large time units, short-term traffic flow forecasts refine the time granularity to a very small range, especially focusing on the immediate traffic situation within 15 minutes. This forecasting model ensures the timeliness and accuracy of the information by collecting and continuously updating traffic data in real time. Based on these accurate predictions, city residents can obtain the best travel path suggestions, thus effectively avoiding traffic congestion caused by temporary construction, traffic accidents and other unexpected situations, and realizing timely traffic diversion. Short-term traffic flow prediction not only improves the convenience of personal travel, but also helps to reduce the economic loss and environmental impact caused by congestion. Therefore, in-depth study and application of short-time traffic flow prediction technology is of great significance to improve the level of urban traffic management and optimize the travel experience of residents [3]. Therefore, this paper will talk about the related theories of short-time traffic flow forecasting, the basic model classification of short-time forecasting, the general process of short-time traffic flow forecasting and the one short-time traffic flow forecasting method, i.e., the time series forecasting model, as well as their advantages and disadvantages.

Addressing the serious challenges of increasing traffic supply-demand imbalance and frequent congestion in China's urbanization process, this paper points out that urban traffic congestion seriously affects the quality of people's daily lives and causes economic losses, excessive resource consumption and environmental pollution. The article emphasizes that traditional measures to alleviate traffic congestion can no longer solve the problem fundamentally, therefore, research and practice of new methods based on traffic information have become a priority. Short-time traffic flow prediction, as the key to judging traffic conditions and making decisions on travel paths, can provide better assisted decision-making tools for residents to travel, effectively divert urban vehicles and avoid traffic congestion. This paper will discuss in detail the relevant theories of short-term traffic flow forecasting, the classification of basic models, the general process and the time series forecasting model, and discuss the advantages and disadvantages of the time series forecasting model.

2. Theories Related to Short-Term traffic volume Prediction

Currently, traffic volume dynamic prediction algorithms are categorized into two major types, the first one relies on vehicle-mounted GPS/GIS for macro prediction of flow. The second type relies on road networking requirements to predict the traffic volume for 5 minutes or even shorter to improve the prediction accuracy. The predictions include traffic volume, average density, path length, average speed, etc [4].

The model used for short-term traffic volume prediction should have the following characteristics. time-adaptive, the prediction of traffic volume will affect the traveler's route choice, and the traveler's route choice will, in turn, affect the accuracy of the traffic volume prediction. Changes in the road environment will bring about abnormal changes in traffic volume, and the model should be able to make

DOI: 10.54254/2755-2721/111/2024.CH18112

correct predictions based on noisy historical data. Changes in the road environment can bring about abnormal changes in traffic volume, and the model should be able to make correct predictions based on noisy historical data.

3. General Process for Short-Term traffic volume Prediction

Pre-processing of traffic volume data. Due to traffic sensor hardware failures, noise interference and communication failures often lead to erroneous data and loss of data. For this reason, for different points in time, the use of weighted average or historical data averaging methods such as supplementing or repairing traffic volume data, and data filtering, so as to obtain a usable data table.

Statistical analysis of traffic data to find patterns. Generally speaking, foot and automobile traffic through the center and the neighboring areas has weekly similarities, while the traffic volume in the far neighboring areas has seasonal differences, and the traffic volume in the tourist routes has a great relationship with the seasons and the weather [5]. From the data to find out the arrangement of relations, the use of clustering method and other methods to select traffic characteristics to do parameters, to determine the current traffic state characteristics, that is, whether to reach the maximum capacity, is serious congestion, general congestion or smooth.

Modeling. According to the judgment results, when the traffic state is congested, the researchers can apply a neural network model, non-parametric regression model, chaos theory model, cusp mutation model or wavelet model to analyze and model; when the traffic state is smooth, they can apply time series model, Kalman filter model and even historical average model. This can improve the accuracy of prediction and save computational resources in a way. Analyze the output values of the predictive model for compliance. Intelligent control and management using various evaluation indicators (commonly used such as the sum-of-squares error SSE, mean absolute error MAE, mean square error MSE, mean absolute percentage error [6].

4. Classification of Short-Term traffic volume Predictions

Short-term traffic flow prediction shows remarkable diversity, and its classification is mainly based on the different ways of data collection. Specifically, they can be categorized into time series forecasting and spatio-temporal fusion forecasting. Time series forecasting strategies not only rely on current data sets for database analysis, but also integrate historical data for simultaneous simulation and forecasting [7]. In contrast, spatio-temporal fusion forecasting methods not only perform predictive analysis on observation point data, but also incorporate data from upstream and downstream of the road section for integrated prediction and simulation.

In addition, according to whether or not a mathematical model is used, prediction methods can be subdivided into model-driven algorithms and model-free algorithms, and can also be differentiated into parametric and non-parametric prediction. From the perspective of prediction model parameters, they can be further differentiated into parametric modeling techniques and non-parametric modeling techniques [8]. According to the correlation between prediction objectives, prediction methods can also be divided into two categories: linear model-based methods and nonlinear model-based methods.

At the level of forecasting principles, short-term traffic flow forecasting can be summarized into three main categories: firstly, mathematical model-based forecasting techniques, secondly, forecasting methods relying on knowledge-based intelligent models, and finally, integrated forecasting methods. In the first category of methods, it mainly contains several typical models such as autoregressive sliding average model, autoregressive model, sliding average model, and historical average model.

5. Time Series Forecasting Methods

Time series modeling is a common method for describing the statistical properties of time series and a practical method for parameter modeling to deal with dynamic stochastic data. It is mainly divided into two kinds one is nonlinear smooth model and the other is linear smooth model. Among them, nonlinear smooth models mainly include IMA model and autoregressive summation sliding average model

DOI: 10.54254/2755-2721/111/2024.CH18112

(ARIMA); linear smooth models mainly include sliding average model (MA), autoregressive sliding average mixed model (AR-MA) and autoregressive model (AR).

In the process of parameter estimation, the autoregressive summation sliding average model must rely on a large number of uninterrupted time series, but in practice, the omission of data on the model is inevitable. According to the actual situation of the experiment, 15 min is the prediction time interval of the autoregressive summation sliding average model, which is only slightly better than the historical average (HA) method, and it needs to be further explored whether the prediction effect will be better if it is less than 15 min. In addition, the autoregressive summation sliding average model is especially suitable for stable traffic volume, but due to the large amount of data, it will be insufficient in predicting unstable traffic volume [9].

6. Time-space forecasting method

The spatio-temporal fusion prediction method integrates data in both temporal and spatial dimensions with the aim of improving the accuracy of traffic flow prediction. The strategy incorporates data from different locations, covering both upstream and downstream traffic flow information, to construct a more comprehensive traffic behavior model. By analyzing the interdependencies among the observation points, the method can take into account the dynamic changes in traffic patterns that are influenced by the surrounding environment.

Performing spatial-temporal fusion predictions often requires the use of sophisticated machine learning algorithms, such as Recurrent Neural Networks (RNN) or Convolutional Neural Networks (CNN), which are very well suited for working with spatial data while capturing temporal dependencies [10]. These models will utilize historical data, immediate traffic information, and external factors such as weather conditions or road closures to make robust predictions even when the traffic environment fluctuates.

In addition, the effectiveness of the method is typically evaluated based on a variety of metrics, including MAE and Root Mean Square Error (RMSE), to ensure that forecasts are highly consistent with actual traffic flows. This fusion approach not only enhances the credibility of the predictions, but also helps to implement forward-looking traffic management strategies, which in turn improves road safety and reduces traffic congestion. As the research continues to progress, exploring hybrid models that combine multiple data sources is expected to generate more accurate traffic flow predictions.

7. Conclusion

Short-time traffic volume prediction on urban roads plays a vital role in alleviating urban traffic congestion. The real-time and accuracy of short-term traffic volume prediction ensures the smoothness of China's urban roads, provides technical support for effectively solving urban traffic problems, and thus promotes the smooth development of China's transportation industry. Intelligent transportation systems as an important part of smart city construction, urban transportation road network intelligence is the inevitable trend of future urban development. Real-time and accurate short-term traffic volume prediction is an important prerequisite for ITS to provide travelers with reliable travel information and improve the quality of travel, and it is the basis for realizing traffic control and traffic guidance to maximize the operation of the city's transportation network. Therefore, fully exploring the characteristics of urban road traffic volume and improving the accuracy of short-term traffic volume prediction is the key to alleviating urban traffic problems, developing intelligent transportation systems and buildling a smart city. This paper discusses in detail some of the qualities and issues of short-term traffic flow prediction. Based on the spatio-temporal correlation and chaotic attributes of traffic flow, the theoretical framework, model construction, as well as the respective advantages and limitations of time series forecasting and Kalman filter forecasting in forecasting practice are elaborated in detail. As an early developed forecasting technique, time series forecasting has been widely used worldwide, but its applicability is mainly limited to short-term forecasting scenarios of smooth road sections. In contrast, Kalman filter prediction shows a high degree of maturity in the field of linear regression analysis, with proper error control and significant prediction accuracy, especially for prediction in high-traffic areas.

DOI: 10.54254/2755-2721/111/2024.CH18112

However, the method needs to adjust the weights during each calculation, which leads to the shortening of the prediction time when the computational volume increases, and the output of the prediction results is more prone to hysteresis. Therefore, the Kalman filter prediction is not sufficient to cope with the rapid changes in road conditions or unexpected conditions.

References

[1] Liu, J., & Guan, W. (2004). An overview of traffic flow prediction methods. Highway and Transportation Science and Technology, 21(3), 82-85.
[2] Wang, J., Ding, Y., & Wang, A. (2012). Study on driving conditions of motor vehicles in Beijing. Journal of Environmental Engineering and Technology, 2(3), 240-246.
[3] Wang, Q. (2017). Research on spatial and temporal distribution characteristics of traffic congestion in Xi'an based on real-time road conditions (Master's thesis). Northwest University.
[4] Yu, D. (2017). Research on short-time traffic flow prediction problem (Master's thesis). Shandong University.
[5] He, G. G., Li, Y., & Ma, S. (2000). Discussion on short-time traffic flow prediction method based on mathematical model. System Engineering Theory and Practice, 12, 51-56.
[6] Chen, M. (2017). Research on short-time traffic parameter prediction method for urban road network (Master's thesis). Jilin University.
[7] Williams, B. M., & Hoel, L. A. (2003). Modeling and forecasting vehicular traffic flow as a seasonal ARIMA process: Theoretical basis and empirical results. Journal of Transportation Engineering, 129(6), 664-672.
[8] Hobeika, A. G., & Kim, C. K. (1994). Traffic flow prediction systems based on upstream traffic. In Vehicle Navigation & Information System Conference.
[9] Han, C., Song, S., & Wang, C. (2004). Real-time adaptive prediction of short-term traffic flow based on ARIMA model. Journal of System Simulation, (7), 1530-1532+1535.
[10] Lu, H. (2004). Introduction to intelligent transportation systems. Beijing: People's Transportation Press.