Analysis and prediction of traffic flow based on Wavelet-BP neural network

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Abstract. Through on-the-spot investigation, collected data of traffic flow from a certain section of 3rd Ring Road in Beijing, the investigation results were analyzed from the perspective of time and space, macro rules of traffic flow and the influence of incidental traffic events on roads was summarized. The MATLAB software was used to decompose traffic flow data by three-layer wavelet, and the variation characteristics of the detail coefficients were obtained by decomposing the parameters of traffic flow by wavelet. Analyzed the abrupt change phenomenon of the traffic flow parameters, so as to judge whether some traffic incident occurred and which kind of it. With the level of road traffic service, the same moment which anomalous traffic flow data produced theoretically and traffic service levels were greater than or equal to 4 levels was chosen, so as to verify whether the anomalous time point analyzed by wavelet-analysis were precise. Used MATLAB software to establish the prediction model by a neural network, and determined the various parameters, functions, training and testing samples. Coefficients of different parameters in the BP neural network were used to predict the changes of traffic flow in the future. Compared the predicted data with the actually observed traffic flow, the starting time of traffic incident and the anomalous mutation starting point of three traffic flow parameters was consistent. This research had great significance to the future intelligent traffic decision-making.

1. Introduction
City Expressway is taking an important role in city road network and traffic system, which just like a special high-speed road in the city, not only having a large capacity, but also making vehicles could drive in one-directional multi-lane road continuously and cross the road. The rapid development and construction of the expressway have greatly met the demand for the rapid flow of goods and personnel in large and medium-sized cities. According to statistics, the total length of expressways in Beijing only accounts for 8% of the total length of all urban road networks, but the traffic volume taken by expressways accounts for more than 50% of the total motor traffic volume in the whole city[1][2].

Manoel Castro-Neto believes that under some atypical conditions, such as vehicle accidents and bad weather, the precise prediction of short-term traffic flow is a key of traffic management system, which can improve the level and efficiency of traffic management[3]. Li Cunjun, professor of Southwest Jiao Tong University, believes that the traffic flow is a time-varying nonlinear system, its internal and input variables are numerous, have a complex structure[4]. Baher Abdulhai proposed a short term traffic flow prediction system based on delay neural network model. The prediction model uses the traffic flow and occupancy data of certain sections, research the relevant variables of traffic flow forecasting from angle of time and space[5]. Gao Yong and Chen Feng suggest that the wavelet
analysis is used to decompose a set of original traffic flow signal which contains comprehensive information into some time series signal groups\textsuperscript{[6]}. Zhang Xiaoli thought that the method of short-term traffic flow prediction based on wavelet analysis and neural network, can reduce the dimension of multidimensional input by wavelet decomposing, so that the process of traffic flow prediction can accomplish independently by multiple sub networks, which can make the method more precise and less error\textsuperscript{[7]}. Ehsan Mazloumi presented the influence of traffic flow data on the prediction accuracy. The artificial neural network based on historical data, that is, the model based on traffic flow data and time data. Traditionally, the prediction of travel time has a tiny error in accuracy\textsuperscript{[8]}. Wang Xin and Shi Qijin believed that the predicting model and method based on neural network for short-term traffic flow, had both advantages and defects \textsuperscript{[9]}. Lu Haiting said that road traffic system had the basic characteristics of non-linearity, complexity and uncertainty, which determined prediction of short-term traffic flow, could not be solved or completed by a single model or method\textsuperscript{[10]}. Therefore, this paper adopted the multilevel and multi-method from the actual situation. Through deep analysis and research of investigation data, found out the potential law in time and space of road traffic flow in the analysis results, sum up the characteristics of the road traffic events. BP wavelet neural network is used to predict the changes of short-term traffic flow and found out the possible point of time of traffic events and congestion, which provides strong support for transportation decision makers by technology and data.

2. Traffic Statistics and Analysis
This paper used data of traffic flow from the north to the south on the Garden Bridge-Aerospace Bridge section of roads in the 3rd Ring-Road in Beijing, April 21-23 in 2009. Time interval was 10minutes and the span of 0:00-24:00, the data contains parameters: speed, flow, occupancy rate. After removing the possibility of the fault of detector, the anomalous and mutated data of traffic flow are analyzed to come up with the cause. Took time series as a unit, collected actual survey data in three days of 24-hour period and 10min interval, eliminated the occasional and invalid values, and plotted the three parameters of traffic flow in MATLAB software, which are shown in Figure1,2,3.

![Figure 1. Traffic flow in the Garden Bridge-Aerospace Bridge section](image-url)
3. Detection and analysis of traffic incident based on wavelet-analysis

Wavelet analysis is a mathematical analysis method that has the ability to analyze local signals in frequency and time domain. This paper uses the db4 wavelet basis, decomposed the data into three-layers wavelet, collected the approximate coefficient $cA3$ and the detail coefficient $cD3$. The algorithm flow diagram of three-layer wavelet decomposition by MATLAB software, as shown in Figure 4:

![Algorithm flow diagram by MATLAB software](image-url)
The 24-hour continuous traffic flow data of the Garden Bridge-Aerospace Bridge section was collected and analyzed on April 21, and decomposed the three parameters of traffic flow, speed and occupancy rate respectively by the three-layer wavelet to obtain the approximate coefficients and the detail coefficients. Superimposed the fluctuating images of the detail coefficients cD3 of the traffic flow-speed-occupancy rate together. Due to the larger value of the detail coefficients of traffic flow, cD3, reduced the detail coefficients by ten times, and overlaid with the cD3 of two other parameters.

![Figure 5. cD3 overlap diagram of flow-speed-occupancy rate at three locations in April 21st](image)

By comparing the details coefficient of the Figure 5, it can be clearly seen that the road traffic flow-speed-occupancy rate fluctuations. At point A in the Figure 5, the detail coefficient cD3 of the three parameters simultaneously fluctuated violently. Under normal circumstances, when two or more traffic parameters appear obvious changes, it can be determined that where the road appeared anomalous traffic flow, or for special traffic events, like road congestion and so on. Therefore, during the period of time point A, some traffic incidents occurred on the road, but due to other environmental factors, there was a slight hysteresis effect on the fluctuation of the specific parameters. Similarly, at point B, the detail coefficients cD3 of traffic flow, speed and occupancy rate appears the second largest amplitude anomaly fluctuation. Based on the above-mentioned relationship between traffic parameters and specific traffic incidents, there was a traffic jam during the time period shown by Point B.

4. Prediction of traffic incidents based on neural network prediction model

The detail coefficients cD3 of traffic parameters (traffic flow-speed-occupancy rate) of Beijing 3rd Ring Road of the Garden Bridge-Aerospace Bridge section, which obtained from the actual survey on April 21, is selected as the neural network training and testing samples. Select the number of input and output layer nodes are 3 and 1 respectively, through trial calculation and relying on experience, the hidden layer nodes are selected as two, each layer contains 4 neurons, and the initial weights are determined as random numbers [-1 ~ 1].

In determining the learning rate, the moderate learning rate is needed to select, so that time won't be waste too much, or lead to lack of learning time. Therefore, the selection range should be between 0.01~0.8, this paper selected learning rate of 0.2. Learning momentum can effectively restrain the network from being trapped in local minims. The learning momentum selected in this paper is 0.9. In terms of expected error, the expected error value is selected by comparing different expected error networks. In this paper, after many contrast training, the expected error of the sample is chosen to be 0.002.

The three traffic flow forecasting data elements are integrated and superimposed, and the actual road service level data in the predicted time period are compared and analyzed as shown in Figure 6 and Figure 7.
Figure 6. Comparison chart of cD3 prediction and real data

Figure 7. The service grade of the Garden Bridge-Aerospace Bridge section in April 21st 13:00-24:00

The error in neural network in prediction of detail coefficient cD3 of traffic speed, as shown in Figure 8.

Figure 8. The error in neural network in prediction of detail coefficient cD3 of speed
5. Conclusion
This paper conducted a field survey of traffic flow data and a time-space analysis of parameters, and identified the causes of anomalous abrupt change data through mutual proof between different data. In order to determine the cause of anomalous mutation data, wavelet-analysis was used to decompose the actual data by db4 wavelet, analyzed the changes of detail coefficients and approximate coefficients in the actual data, and combined with the flow - speed - share Details of the coefficient cD3 on the specific occurrence of traffic incidents to determine the analysis.

Then, the level of road service is introduced to match the theoretical abrupt change period with the period of the actual road service level equal to 4 or greater, so as to verify whether the traffic flow anomalous point obtained by the wavelet analysis is accurate and confirm the wavelet decomposition. The detail coefficient cD3 obtained from the parameters of traffic flow can be used as one of the methods to determine traffic incidents.

At the same time, a neural network is used for predicting the future trend of traffic flow, and the parameters of BP neural network are analyzed and determined. The BP neural network model is built based on the detail coefficient cD3 obtained after wavelet decomposition, and the traffic parameters are predicted. The analysis result of the comparison with the real data shows that the obvious change of the three traffic parameters over a period of time can be clearly observed after superposition of each coefficient, so as to judge the starting point of occurrence time of anomalous traffic incident. It will have great significance for intelligent traffic decision-making in the future.

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