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Short-term Traffic Flow Model Prediction Based on Wavelet Neural Network

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Abstract

With the development of social economy, the demand for transportation is increasing. People choose to buy their own private cars while improving their living standards. This has led to a large increase in the number of private cars. In today's society, the emergence of shared bicycles is a huge test for the existing transportation system. Therefore, the implementation and control of traffic flow has become increasingly important, and the prediction of short-term traffic flow model is also a hot issue today. Through in-depth study of neural network and wavelet theory, this paper applies wavelet basis function as the activation function of neural network, and uses gradient descent algorithm to correct the error, and obtains a relatively ideal prediction model. In the future, traffic flow can be predicted more accurately.

Keywords

Wavelet neural network; Traffic flow; Accurate prediction.

1. Introduction

With the development of society, China has entered a well-off society in an all-round way, people's living standards have gradually improved, and the number of travel modes available has gradually increased. Auto travel has become the most common travel mode in modern society. China's urban transportation network system is gradually being established. However, with the improvement of the quality of life of our people, the number of vehicles in cities is increasing, and more families choose to buy their own private cars. The traffic demand in cities has increased significantly, with more and more cars, traffic jams, frequent traffic accidents and other problems coming along, which has become the bottleneck restricting the development of cities, and has also become a hot issue of traffic management departments. But at present, China's transportation system cannot meet the needs of people in modern society for transportation network. Scientific and effective traffic management can reduce the accident rate and alleviate the problem of traffic congestion during rush hours. Therefore, short-term prediction of the future traffic situation based on the existing data has become the focus of all departments. It is an indispensable part of modern traffic. The traffic management department can take early warning and traffic control measures for relevant traffic intersections according to the short-term prediction results of traffic flow to solve the problem of traffic congestion at peak hours. With the current development of transportation demand in China, we need to design a more perfect and reasonable transportation system to support the rapid economic development. Therefore, how to design a reasonable transportation system has become a difficult problem at present. The traffic data used in short-term traffic flow prediction has complex spatial and temporal dependence. The traffic flow of a certain section will be affected by other sections at different locations, as well as by the historical time of the section. Moreover, the traffic conditions of the previous time of the section will also affect the traffic flow of other

sections. Therefore, the traffic flow has the characteristics of uncertainty, nonlinearity and real-time change. We will build a more accurate prediction model of traffic flow according to the characteristics of short-term traffic flow.

At present, scholars from all countries have invested a lot of human and material resources in the intelligent transportation system. Since the 1980s, China has also begun to study the intelligent transportation model prediction. Over the years, it has also made significant achievements, which can be divided into the following aspects:

(1) Based on nonparametric regression model, it is a regression method without knowing the total distribution. It is applicable to the modeling of uncertain and nonlinear dynamic systems. It has a very good observability for different traffic conditions at different times and different traffic conditions. This method is easy to operate and realize, and is applicable to the complex space environment of traffic network, It can also accurately predict traffic flow, etc. The common methods are K-nearest neighbor regression state regression and kernel nearest neighbor state regression, but nonparametric regression also has disadvantages, such as the slow convergence rate of his estimation, half of which is applicable to large sample data, while the prediction effect for small samples is poor, and the selection of parameters is generally very complex.

(2) Based on the RAIMA model and the prediction model of time series, its main idea is to treat the data series formed by the prediction object as a random series, and roughly describe the random model through curve fitting and parameter estimation. This time-meaningful sequence is also known as dynamic data. It has a good fitting effect for traffic flow, which changes at all times in time and space.

(3) Based on the model of Kalman filter, Kalman filter is an algorithm for filtering time-varying random signals, which can remove the impact of noise on the predicted data in the future. It is a prediction algorithm based on probability and statistics, which is a filtering method for changing data over time. This model has high flexibility, wide applicability, and can remove the impact of noise on the predicted value, So as to achieve a more accurate prediction of the traffic situation.

(4) Prediction models based on deep learning, such as SVM support vector machine model, Markov model, etc., can be understood as neural networks with multiple hidden layers, and can approach any complex function by learning a deep nonlinear network structure [1]. There are many functional relationships in real life traffic, but these functional relationships cannot be expressed by simple linear functions, therefore, this kind of learning of nonlinear model is often used to wirelessly approximate the real functional relationship and predict and guide the future.

(5) The prediction model based on neural network is a prediction model that imitates the human brain neural model. It is a model with large-scale parallel, distributed storage and processing of data, and adaptive and self-adjusting. This model is especially suitable for us to simulate traffic flow and predict future traffic flow. It has parallel distributed processing, high fault tolerance, and can more fully approximate complex functional relationships, It has certain prediction effect for traffic flow.

The above models are all single models to predict traffic flow, but with the development of the Internet, many application combination models have emerged in modern society to predict data, such as the neural network model based on swarm intelligence algorithm. They apply many new models to too many single models to make the model more accurate and efficient.

Traffic flow can be divided into short-term traffic flow and long-term traffic flow according to the time span. The research time span of long-term traffic flow is usually in years, seasons, months and days, while the time span of short-term traffic flow is generally not more than 15 minutes. The main content of this paper is short-term traffic flow. According to the existing research findings, the traffic flow of a section of road at a certain time in the current traffic

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network is related to the traffic flow of several periods before the section, and the short-term traffic flow has the characteristics of quasi-cycle within 24 hours [2]. This paper mainly collects the relevant traffic flow data according to the above collected data, constructs the wavelet neural network model, and uses matlab to train and optimize the model, and finally obtains a neural network model that can accurately predict the traffic situation.

2. Relevant Contents of Wavelet Theory

2.1. Basic content of wavelet theory

Wavelet is a kind of waveform with length priority and average value of 0. Its characteristics are as follows: ① The time domain has tight support or approximate tight support; ② The DC component (mean value) is 0 [3]; The wavelet function is obtained by translation and scaling of a parent wavelet function, and wavelet analysis is to decompose the signal into a series of wavelet functions. Wavelet transform refers to the translation of a basic wavelet function (t) and the inner product of it with the signal x (t) to be analyzed at different scales a [4].

2.2. Wavelet transform

Wavelet transform is the mathematical transformation of the signal we obtained at the beginning. For example, in the short-term traffic flow model studied in this paper, the information we collected must contain the relevant data of the traffic lights at each intersection in the traffic network. When we process the signal, we will carry out the mathematical transformation. The signal is a time-domain signal, which will change periodically with time, Through complex mathematical transformation of the signal, such as Fourier transform [5], the signal spectrum can be obtained by Fourier transform, and the change of this signal in time domain can be visualized. However, Fourier transform also has some shortcomings. It only gives the spectral components of the signal, but does not give any information about the occurrence time of these components. Therefore, Fourier transform is not suitable for analyzing non-stationary signals. It can only show which frequency components are included in the signal. However, the changes of the short-term traffic flow related signals we studied in this paper are unstable and cannot be processed by Fourier transform. Wavelet transform can improve the shortcomings of Fourier transform, and it can deal with some non-stationary signals [6]. It provides the time-frequency representation of the signal and the appearance of specific spectral components at a specific time often has special significance. It will be very useful for our research to know the time interval of these specific spectral components. Wavelet transform can provide both time and frequency information [7]. This is of great significance for short-term traffic flow data.

3. Content of Neural Network

3.1. Basic overview of neural network

Neural network algorithm is an algorithm model created by people according to the research of human brain neural network and simulating the process of our brain neural work. Neural network is also called artificial neural network.

When the signal passes through the afferent nerve to the dendrite, the dendrite will transmit the afferent signal to the nucleus, and the cell will check the signal for processing, including whether the signal reaches the threshold of action potential. If the signal reaches the threshold, it will cause nerve impulse and transmit the signal downward; If the signal does not reach the threshold of action potential, there will be no impulse and no further conduction. When a nerve impulse is generated, the input signal processed and combined by the nucleus will be transmitted to the axon terminals through the axon, which will transmit the signal to the next

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neuron or effector and other working areas. This is the working process of brain neurons. Multiple neurons connect to form the neural network of our human brain.

Through in-depth study of the working process of brain neurons, people have constructed artificial neuron models by simulating brain neurons.

The input is equivalent to the dendrites of the brain neurons, which are used to input signals or data. The process of weighting and summation in the figure is equivalent to the process of merging or processing the cell check signals in the brain neurons. The output is the process that the axons and axon terminals in the brain neurons transmit the processed signals to the next neuron or effector.

3.2. Development of neural network

The earliest model of neural network is the single-layer neural network model, also known as the perceptron model. Its structure is as follows:

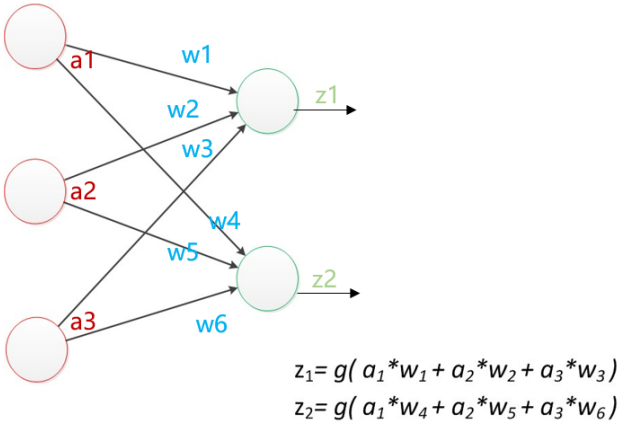

Figure 1. Single-layer neural network model

In perceptron, there are two levels. They are input layer and output layer. The input layer is only responsible for inputting the transmitted data and does not perform calculations. The output layer needs to calculate the input of the previous layer. He has only one computing layer. So it is also called single-layer neural network.

After the single-layer neural network, people carried out in-depth research and got the two-layer neural network model, whose structure is shown in the following figure:

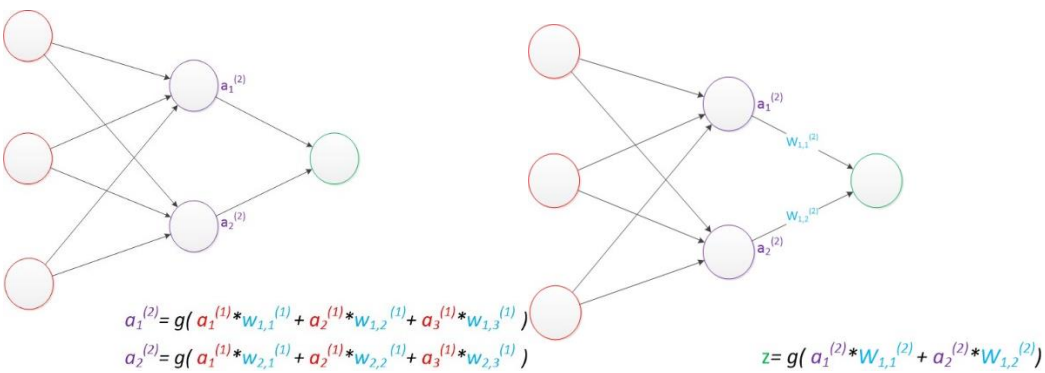

Figure 2. Model of two-layer neural network

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Two-layer neural network means that the neural network has two calculation layers. If one layer is added on the basis of single-layer neural network, the former two-layer network will become three layers. The former input layer will remain as the input layer, while the former output layer will become the middle layer. After adding one layer as the output layer, we call the middle calculation function the activation function.

After the advent of two-layer neural networks, multi-layer neural networks have gradually emerged. Multilayer neural networks are built on the basis of two-layer neural networks. The output layer of the previous network is changed into the middle layer, and another layer is added as the output layer. This is repeated, and the multi-layer neural network will be obtained.

3.3. Content of wavelet neural network

Principle of wavelet neural network: wavelet neural network is a specific neural network that uses wavelet basis function as the activation function of the neural network. It is a neural network that allows the forward propagation error of the signal to propagate back.

The output calculation formula of the calculation layer is as follows:

$$h(j) = h_j\left(\frac{\sum_{i=1}^{k}\omega_{ij}x_i - b_j}{a_j}\right) \quad j = 1,2,\cdots,l \tag{1}$$

The wavelet function used in this paper is the Morlet mother wavelet basis function, and the mathematical formula is [8]:

$$y=\cos(1.75x)e^{-x^2/2} \tag{2}$$

The image of the function is shown below:

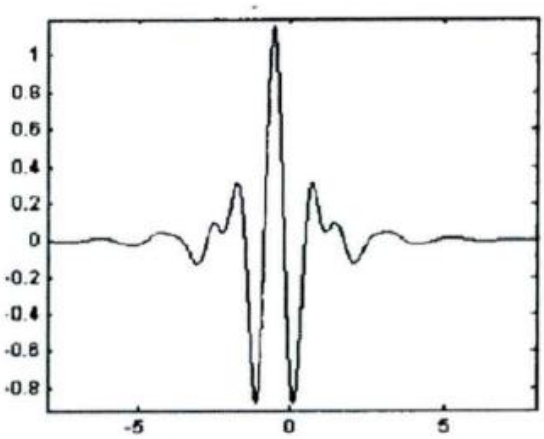

Figure 3. Image of wavelet function

The output layer calculation formula of wavelet neural network is:

$$y(k)=\sum_{k=1}^{m}\omega_{ik}h(i) \quad k=1,2,3,\ldots,m. \tag{3}$$

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The weight parameter correction method of the wavelet neural network is similar to the weight correction algorithm of the BP neural network. The gradient descent algorithm is used to correct the weight value of the network, the parameters of the wavelet basis function and the structure of the network, so that the predicted value of the wavelet neural network can continuously approach the expected output value. The correction process is as follows [4]:
① Calculate network error

$$e = \sum_{k=1}^{m} yn(k) - y(k) \tag{4}$$

Where, yn (k) is the expected output; y (k) is the prediction output of wavelet neural network.
② Compare the predicted value with the real value to get the error e, let e back-propagate and correct the model.

$$\begin{aligned} \omega_{n,k}^{(i+1)} &= \omega_{n,k}^{i} + \Delta\omega_{n,k}^{(i+1)} \\ a_k^{(i+1)} &= a_k^{i} + \Delta a_k^{(i+1)} \\ b_k^{(i+1)} &= b_k^{i} + \Delta b_k^{(i+1)} \end{aligned} \tag{5}$$

Where, $\Delta\omega_{n,k}^{(i+1)}$、$\Delta a_k^{(i+1)}$、$\Delta b_k^{(i+1)}$ are calculated according to the network prediction error

$$\begin{aligned} \Delta\omega_{n,k}^{(i+1)} &= -\eta \frac{\partial e}{\partial \omega_{n,k}^{(i)}} \\ \Delta a_k^{(i+1)} &= -\eta \frac{\partial e}{\partial a_k^{(i)}} \\ \Delta b_k^{(i+1)} &= -\eta \frac{\partial e}{\partial b_k^{(i)}} \end{aligned} \tag{6}$$

Where, η is the learning rate.

4. Short-term Traffic Flow Prediction Model Based on Wavelet Neural Network

4.1. Model establishment

According to the characteristics of short-term traffic flow, we can build the following wavelet neural network model: the network model has: ① input layer, ② calculation layer, ③ output layer. The input layer is used to input data signals and traffic flow at the first n time points of the current time node, while the calculation layer is composed of wavelet basis functions to predict the future flow value, and the output layer is used to output the predicted value of the model.

We collected traffic flow data for four days, and recorded 384 data every 15 minutes. The first three days, the first 288 data, were taken as the training sample training model to predict the traffic flow on the fourth day [9], and compared with the traffic flow data on the fourth day of the collected data, and then corrected the parameters of the model according to the gradient descent algorithm error correction model described above, When the number of error correction is less than the set number of iterations, stop error correction to get the final model.

4.2. Programming implementation

In this paper, matlab is chosen as the programming environment to realize the prediction of short-term traffic flow model based on wavelet neural network.

Download the required training samples and test samples from the database, initialize the weights, parameter values and network structure, and perform a series of data processing on the downloaded data, such as normalization. After network training and error correction, appropriate weights and network parameters are obtained, and the final model is used to predict the future traffic value.

4.3. Analysis of model prediction results

From the prediction results of the model, we can see that the wavelet neural network can predict the short-term traffic flow model more accurately. Compared with the single neural network model, the wavelet neural network is more accurate in predicting the model. The error correction model is used to modify the model according to the existing data, so that the model can be better applied in the real society. However, the model has the following problems in the process of implementation: first, the gradient descent method that I used in error correction. In practical applications, the algorithm runs long, slow, and is easy to fall into the local optimal solution.

5. Summary

In this part, we use the wavelet function as the activation function of the neural network to code in matlab, build the prediction model of the neural network, input the collected data of the wavelet neural network for training, and then use the gradient descent method in machine learning to carry out error correction and parameter adjustment on the model, finally get a more accurate prediction model, and visualize the prediction results, It is proved that the model is more accurate and applicable in the prediction of short-term traffic flow, and is of great significance for the traffic control of relevant departments.

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