A Short-term Traffic Flow Prediction Method Based on Wavelet Analysis and Neural Network

Chai Yanchong[1], Huang Darong[1], Zhao Ling[1]

1. College of Information Science and Engineering,Chongqing Jiaotong University,Chongqing 400074
E-mail: hcx1978@163.com

Abstract: A short-term traffic flow predicting mode is discussed based on the wavelet analysis and neural network. First, the basis theory of Mallat wavelet and BP neural network are introduced in detail. Secondly, a short-term traffic flow predicting model is constructed combining with Mallat wavelet and BP neural network. Meanwhile, the evaluating criterion of the prediction model is given according to the features of traffic data. Thus, the error structure of the constructed forecasting model is analyzed. Finally, the effectiveness of the short-term traffic predicting model is verified by using Chengdu-Chongqing high-speed detection information.

Key Words: Wavelet Analysis, Neural Network, Traffic Flow, Prediction Model

1 INTRODUCTION

In recent years, the transportation has become an important part of people's life; the traffic flow forecasting has become one of the most popular research directions[1]. At present, the domestic and foreign researchers using various disciplines knowledge of short-term traffic flow forecasting method to do some research, successively put forward the spectrum analysis, historical average linear regression, time series and Kalman filtering, nonparametric regression[2-3], neural network and dynamic traffic assignment, gray theory, chaos theory, the prediction method of support vector machine (SVM)[4-6], etc. Combination forecast combines the various forecasting methods to form a new prediction method. It can get higher prediction precision through the information integration of scattered single prediction of uncertainty and reduce overall uncertainty.

Because the wavelet analysis has the innate ability of solving unsteady time series, by wavelet decomposition, to extract low frequency approximation part of the original signal and high frequency detail, so that the original signal apart to analysis, to a more comprehensive, comprehensive considering the characteristics of the original signal. And the function approximation characteristic of BP neural network, which is beneficial to short-term traffic flow forecasting of regularity is not strong[7].

Based above, a short-term traffic flow model is constructed combining wavelet theory and neural networks in this paper. The basic idea is as following: first, the traffic flow information is divided into low-frequency signal and high-frequency signal by using wavelet decomposition to eliminate noise. And the decomposed signal may be processed by neural network to get the weight value of training network layer. Then, we may reconstruct a new traffic signal to achieve a better prediction effect for traffic systems by combing the features of low-frequency signal and high-frequency signal.

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2 A BRIEF INDRODUCTION OF WAVELET ANALYSIS AND NEURAL NETWORK

2.1 Introduction of wavelet analysis theory

Wavelet analysis and wavelet transform was developed in the mid 80s. It is considered to be the breakthrough of Fourier analysis method and has many excellent features. The basic idea of wavelet transform is using signal in a bunch of basis function R.Vishny space projection on the characterization of the signal. It has good localization property both in the time domain and frequency domain. There are widely used of Haar wavelet, Mexican hat wavelet (Marr), Morlet wavelet, Daubechies wavelet, etc. Mallat wavelet will be used in this article, and then we will mainly introduce it.

2.2 Decomposition and reconstruction of MALLAT tower wavelet algorithm

Mallat algorithm is put forward by S.Mallat. It is a kind of pyramid algorithm for solving wavelet coefficients, Mallat algorithm is expressed as:

$$\begin{cases} C_{j+1} = HC_j \\ D_{j+1} = GD_j \end{cases} \tag{1}$$

The scope of j is: $j = 1,2\cdots J$

In the formula (1), low-pass filter and a high-pass filter are respected as H and G. The C_0 is defined as the original signal X. The formula X can be decomposed into $d_1, d_2, \ldots, d_j$ and c_j (j is the maximum decomposition level) . c_j and d_j are referred to in the resolution 2^{-j} of the original signal approximation signal and detail signals. Layers of detail signal and approximation signal are the original signal in different frequency bands adjacent components.

Using Mallat algorithm to decompose wavelet , after each decomposition, the points of the details signal and approximate signal will be reduced by half than before. Reconstruction algorithm can be used for reconstruction after decomposition . Reconstruction algorithm is decomposition algorithm of inverse process. Reconstruction algorithm is described as follows:

$$C_j = H^* C_{j-1} + G^* D_{j-1} \quad (2)$$

The scope of j is $j = J-1, J-2, \cdots 0$.

Where, H^* and G^* are the dual H and G operator. Using wavelet reconstruction algorithm to reconstruct the decomposition signal can increase the number of points of signal. To reconstruct of $d_1, d_2, \ldots, d_j$ and c_j , respectively, for $D_1, D_2, \ldots, D_j$ and C_j , they are in the same points with the original signal, and $X = D_1 + D_2 + \ldots + D_j + C_j$.

2.3 Neural network overview

A neural network is a program or system which is modeled on the human brain and is designed to imitate the brain's method of functioning, particularly the process of learning. Its idea is to build a functioning inspired by biological neural network functions generated, usually through an optimized type of learning based on mathematical statistical methods. In the perception of the field of Artificial Intelligence, this method has more advantages than formal logic reasoning calculus.

Neural network have characteristics of nonlinear, non-limiting, non-fixed-length and non-convex. According to a different structure, function, and learning algorithms, neural networks can be divided into perception neural network, linear neural network, BP neural network, Path the neural network, competitive neural network, feedback neural network and random neural network. Due to the BP neural network can approximate any function at any precision, so it is possible to predict the problems competently.

2.4 The transfer function of the BP neural network

Transfer function is mainly used to control the activation of the neural network input to the output effect, achieve the transformation between input and output, and it is converted into a finite output when the network input is infinite. There are three classes of typical transfer function:linear function, threshold function and S-type function.S-type function is also called compression and logic functions and it is most widely used. An arbitrary input value may be compressed to [0, 1]. Notice that logarithmic s-type function and hyperbolic tangent sigmoid function are also S-type function. The relation of logarithmic s-type function is:

$$f = \frac{1}{1 + \exp[-(n+b)]} \quad (3)$$

The relation of hyperbolic tangent sigmoid function is:

$$f = \frac{1 - \exp[-2(n+b)]}{1 + \exp[-2(n+b)]} \quad (4)$$

3 THE COMBINATION OF WAVELET ANALYSIS AND NEURAL NETWORK

3.1 The combination of wavelet analysis and neural network

There are two ways of combining wavelet analysis and neural network: One is using wavelet analysis to process the signal for feature extraction, and then these features are extracted into neural network; Another is called wavelet neural network or wavelet network.In this paper,we use the first kind of combination way to establish the mathematical model.

3.2 Traffic flow forecasting model

The combination of wavelet and neural network solve the prediction problem greatly. First,Using wavelet transform to extract the useful information.Then we use neural network to process each part of the information for prediction.This is the general idea of the design.Prediction model is as follows:

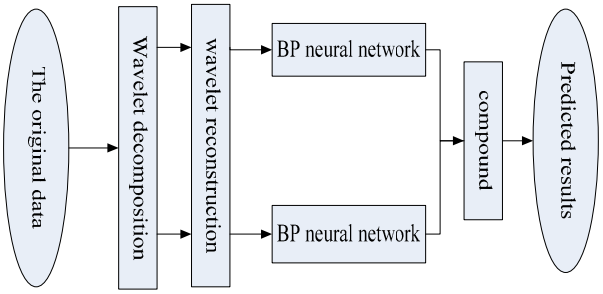

Fig 1. Prediction model

In order to evaluate results of the prediction model, we select the mean absolute error (MAE), mean square error (MSE) and equal coefficient (EC) as the basis of evaluation index.

① Mean absolute error（MAE）

$$MAE = \frac{\sum_{i=1}^{n} |y_i - q_i|}{n} \quad (5)$$

② Mean square error（MSE）

$$MSE = \frac{\sqrt{\sum_{i=1}^{n} (y_i - q_i)^2}}{n} \quad (6)$$

③ Equal coefficient（ EC）

$$EC = 1 - \frac{\sqrt{\sum_{i=1}^{n} (y_i - q_i)^2}}{\sqrt{\sum_{i=1}^{n} (y_i)^2} + \sqrt{\sum_{i=1}^{n} (q_i)^2}} \quad (7)$$

4 ALGORITHM SIMULATION AND TEST

Traffic flow prediction is to judge future traffic flow trends according to the current and historical data because of the traffic flow data are nonlinear and stochastic.It is generally believed that predict time span is no more than 15 min for short-term traffic flow forecasting.

This prediction model was applied to predicting the traffic flow of Chengdu-Chongqing expressway (Chongqing, Chengdu). The observation time is from October 16, 2010 to October 22, 2010. Because the data of traffic flow is too huge in one day, so we extract an hour-long data as the experimental data randomly.

We choose the single hidden layer neural network for function fitting, and use a period of short time series to train the neural network. The number of hidden layer neurons is from 8.We compare the effect of different numbers of neurons in hidden layer to determine the numbers of neurons by emulating.The results is shown in the following table.

Table 1 number of hidden layer neurons

The number of hidden layer neurons	MSE	MAE	EC	Network convergence steps
8	0.0208	0.1905	0.8641	No convergence
9	0.0191	0.1916	0.8759	No convergence
10	0.0130	0.0724	0.9162	No convergence
11	0.0106	0.0815	0.9318	No convergence
12	0.0096	0.0705	0.9380	No convergence
13	0.0055	0.0587	0.9648	150
14	0.0055	0.0599	0.9650	120
15	0.0054	0.0607	0.9651	119

Based on the above, we can draw a conclusion that the neural network is converged when the number of hidden layer neurons in more than 12.Due to the cause that increasing the number of neurons will bring the burden of network training and take up a lot of time and space, we take 15 neurons to achieve better results.In order to select suitable training function, this paper chose different BP training algorithm for short-term traffic flow forecasting. After fully training ,the prediction error is shown in the table below.

Table 2 all kinds of prediction error of the BP training algorithm

BP training algorithm	MSE	MAE	EC	Network convergence steps
The standard BP algorithm	0.0502	0.7285	0.6313	No convergence
Momentum BP algorithm	0.0541	0.7755	0.5992	No convergence
Learning rate variable momentum BP algorithm	0.0102	0.1347	0.9340	No convergence
Fletcher - Powell conjugate gradient method	0.0070	0.0348	0.9552	No convergence
Polak - Ribiere conjugate gradient algorithm	0.0054	0.0767	0.9650	202
Powell - Beale conjugate gradient algorithm	0.0055	0.0665	0.9649	117
BFGS algorithm	0.0054	0.0699	0.9662	102
LM algorithm	0.0051	0.0653	0.9670	12
OSS algorithm	0.0054	0.0748	0.9650	260

As can be clearly seen from the above table,the standard BP algorithm,momentum BP algorithm,learning rate variable momentum BP algorithm and Fletcher-Powell conjugate gradient method are not convergence. Polak-Ribiere conjugate gradient algorithm and Powell-Beale conjugate gradient algorithm are convergent. But the speed of convergence is low.LM algorithm is the fastest convergence algorithms,but LM algorithm occupy large space and it can't combine with wavelet analysis well.At the same time,BFGS algorithm has good effect of convergence,and it has little error,so we choose BFGS algorithm.

Then we select 10 seconds as time interval to make simulation.In order to make the results more credible,We increase neural network prediction model and weighted moving average prediction model for comparison. The results are as follows.

Firstly the wavelet transform does decomposition analysis on traffic flow signals , then through the single reconstru cting ,high frequency details can be got ,as shown in the figure 2. After neural network training 696 times, its err or ratio can be as low as 0.01.

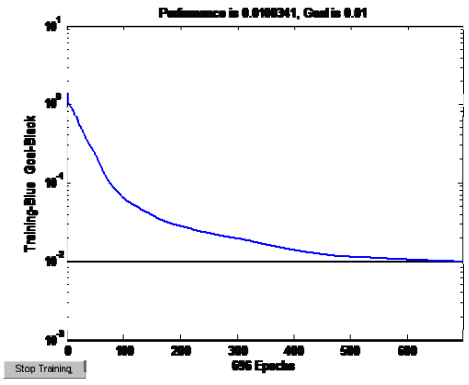

Fig 2. High frequency detail error performance curve

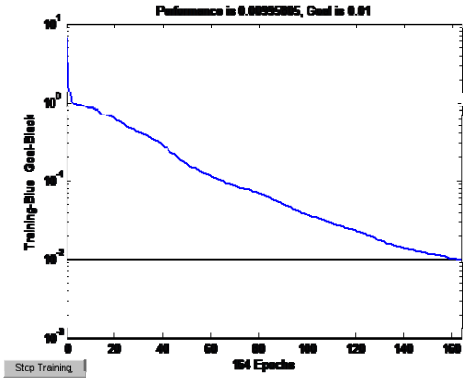

Fig 3. Low frequency approximation section error performance curve

As shown in the figure 3,after neural network training 164 times,low frequency approximation section can be got,its error ratio can be low as 0.01.

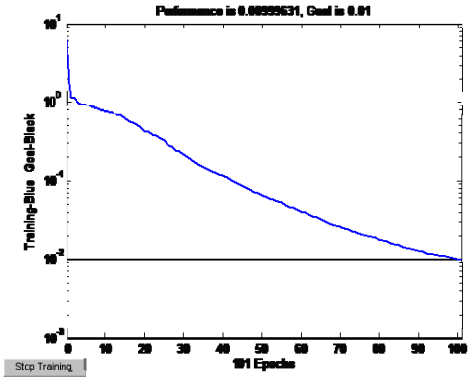

Fig 4. Only neural network forecasting error performance curve

When we only use neural network to predict,the error performance curve is as shown in the figure 4,after neural network training 101 times,its error ratio can be low as 0.01.

The forecasting result of using the wavelet analysis and neural network combination prediction model is shown in the figure 5.The forecasting result of only using neural network prediction model is shown in figure 6.The forecasting result of using weighted moving average prediction model is shown in the figure 7.

In the three picture,the red line is the prediction curve, the blue line is the actual curve.

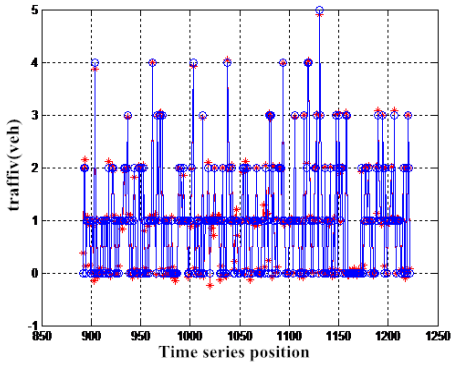

Fig 5.wavelet analysis and neural network combining forecasting curve

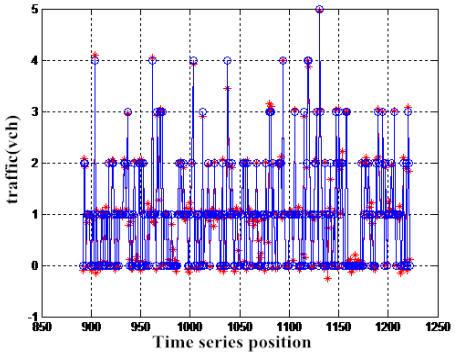

Fig 6. neural network prediction fitting curve

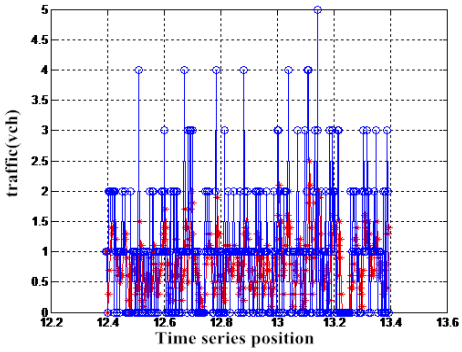

Fig 7. weighted moving average forecasting fitting curve

The error fluctuation curve of three kinds of prediction model are shown below.

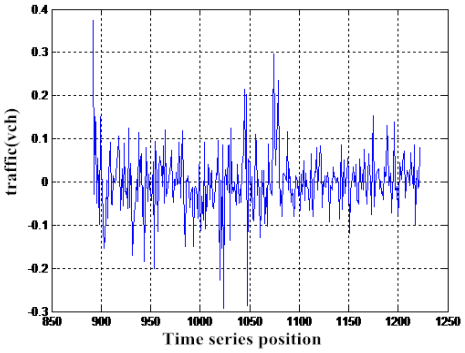

Fig 8. Combined forecast error fluctuation curve

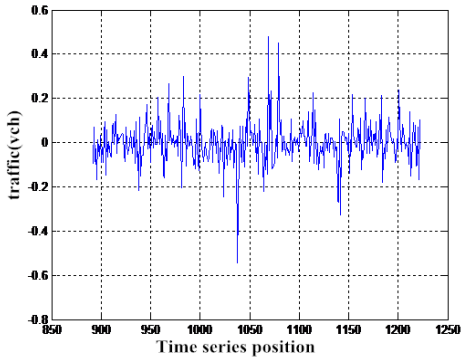

Fig 9. Neural network prediction error fluctuation curve

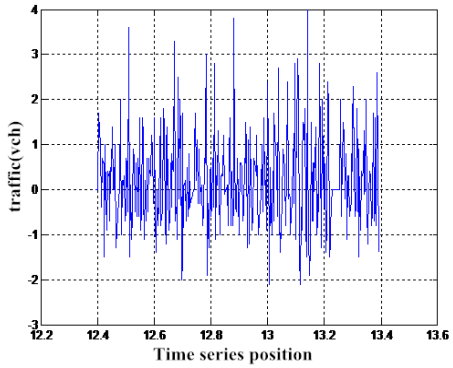

Fig 10. Using the weighted moving average method of error fluctuation curve

The results show that the prediction effect are similar between the combined prediction model of wavelet and neural network and the prediction model of only using neural network, the prediction effect of using weighted moving average method is poor.

The error ratio of using the combined prediction model of wavelet and neural network is within 0.4.The error ratio of only using the neural network is within 0.6.The error ratio of only using weighted moving average method is within 4.

We used mathematical statistics evaluation criteria for the evaluation of these three models.

For wavelet analysis and neural network forecasting method of combining:

MSE=0.0040

MAE=0.0508

EC=0.9743

For neural network forecasting method:

MSE=0.0055

MAE=0.0691

EC=0.9650

For the application of the weighted moving average method:

MSE=0.0589

MAE=0.8199

EC=0.5395

5 CONCLUSION

- Convergence speed is faster if we only use neural network to predict.This is because the wavelet decomposition increases the complexity of the time series. Meanwhile it improves the prediction precision.
- The effect of using wavelet analysis and neural network combining forecasting results is best.The next is the neural network prediction model.The worst is the weighted moving average prediction model.
- There is still a little flaw in prediction model established in this paper. Such as that we didn't do too much discussion about the layer number of wavelet decomposition ; There is plenty of room to improve.

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