PREDICTION FOR SHORT-TERM TRAFFIC FLOW BASED ON OPTIMIZED WAVELET NEURAL NETWORK MODEL

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ABSTRACT

Short term traffic forecasting has been a very important consideration in many areas of transportation research for more than 3 decades. Short-term traffic forecasting based on data driven methods is one of the most dynamic and developing research arenas with enormous published literature. In order to improve forecasting model accuracy of wavelet neural network, an adaptive particle swarm optimization algorithm based on cloud theory was proposed, not only to help improve search performance, but also speed up individual optimizing ability. And the inertia weight adaptively changes depending on X-conditional cloud generator which has the stable tendency and randomness property .Then the adaptive particle swarm optimization algorithm based on cloud theory was used to optimize the weights and thresholds of wavelet BP neural network, Instead of traditional gradient descent method . At last, wavelet BP neural network was trained to search for the optimal solution. Based on above theory, an improved wavelet neural network model based on modified particle swarm optimization algorithm was proposed and the availability of the modified prediction method was proved by predicting the time series of real traffic flow. At last, the computer simulations have shown that the nonlinear fitting and accuracy of the modified prediction methods are better than other prediction methods.

KEYWORDS

Traffic flow prediction, Wavelet neural network, cloud PSO algorithm, cloud theory.

1. INTRODUCTION

With the accelerating urbanization and increasing traffic flow and serious traffic jams arise in big cities of china, intelligent transportation system draws the attention of people, since accurate traffic flow forecasting in real time is the foundation of the intelligent traffic management, the short-term traffic flow prediction becomes particularly important.

In general, short-term traffic flow prediction refers to forecasting the traffic flow of 5-15 minutes, the larger the time range is, the harder to predict traffic flow changes, and research generally focused on short-term traffic flow prediction, there are various of prediction methods, such as the classical method with historical trend method, time series method, kalman filtering method, regression analysis, etc. [1]. But the linear model cannot adapt to the high randomness characteristics of road traffic flow, based on the complexity of traffic flow, nonlinear, time-varying and nonlinear prediction model arises at the historic moment, for example, neural network, fuzzy theory, chaos theory and cellular automata. With the advantages of strong fault

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tolerance, the neural network model was widely used in short-term traffic flow prediction, but for neural network structure is complex, parameter training needs a long time. Based on the above reasons, many scholars adopt the swarm intelligent algorithm to improve neural network for short-term traffic flow prediction, In Literature [2], the cuckoo algorithm was used to optimize the BP neural network parameters, take advantage of the cuckoo algorithm's faster convergence speed, since it increases the information exchange between groups.

In Reference [3], adaptive mutation particle swarm optimization (PSO) algorithm was proposed to optimize the BP neural network model, since the improved PSO algorithm has the bigger possibility to find a more optimal value, thus higher accuracy was achieved than basic PSOBP prediction model. In Literature [4] , particle swarm algorithm was optimized by chaos theory, and the neural network model which optimized by wavelet of chaotic particle swarm was adopted for short-term traffic flow prediction, and optimal results are obtained. This fully illustrates the particle swarm optimization (pso) algorithm has a superiority in optimizing neural network prediction model. Particle swarm optimization (PSO) is a kind of algorithm based colony intelligent. It has the ability of global search, and it is very simple. To improve prediction accuracy, in this article, CPSO algorithm is presented to optimize the parameters of model.

2. ANALYSIS OF WAVELET NEURAL NETWORK

The average wave of Wavelet is 0 with limited length, wavelet analysis means using wavelet function to approximate or express function or signal, and wavelet neural network is wavelet theory combined with neural network, its basic structure is shown in figure 1.

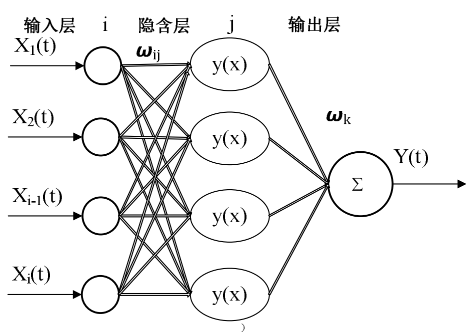


Figure 1 structure of wavelet neural network

In Figure 1, ω_{ij} and ω_k represent the weights of neural network, y (x) denotes wavelet basis function. This article selects the Morlet mother wavelet basis function as basis function [5], the formula is as follows:

$$y = \cos(1.75x)\, e^{\frac{x^2}{2}} \qquad (1)$$

Output formula of the hidden layer as follow:

$$h(j) = h_j \left[\frac{\sum_{t=1}^{N} \omega_{ij}\, x_i - b_j}{a_j}\right], \ j = 1, 2, \ldots, l \qquad (2)$$

The h (j) denotes the output of hidden layer jth node; ω_{ij} denotes the weights between input layer and hidden layer. b_j denotes translation factor of the wavelet basis function h j , a_j denotes the scale factor of wavelet basis function h j,h_j denotes the wavelet basis function, the formula of output layer is as follow:

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

Among them, the ω_{ik} denotes output of the hidden layer .In this paper, wavelet neural network parameter optimization criteria are determined by the minimum performance index function, Namely the function value is smaller, the parameters of wavelet neural network is better, the performance function is defined as:

$$f(x) = \frac{1}{N} \sum_{t=1}^{N} [y(t) - y'(t)]^2 \tag{4}$$

Among them, N denotes sample number, $y(t)$ denotes prediction output, $y'(t)$ and denotes the actual output.

3 IMPROVE THE PARTICLE SWARM ALGORITHM BASED ON CLOUD MODEL

In 1995, R.C. Eberhart and j. Kennedy, two scholars foraging birds behavior in nature into computer language, forming particle swarm optimization algorithm, a kind of widely used swarm intelligence algorithm[6]. Each particle represents a solution in the search solution space, particles using speed decided their flight direction and distance, and integrate the ego and the experience of the group members, collaborative learning and social learning itself, adjust real-time local and global optimal solution of the whole population Continuously and dynamically, constantly update location in the solution space, search until the end of the iteration [7].Set a populations composed of m particles, each particle optimize itself by flight and iteration. The speed of ith particles can be represented as $V_i = (v_{i1} v_{i2}, \ldots, v_{iD})$, position vector can be represented as $X_i = (x_{i1}, x_{i2}, \ldots, x_{iD})$,The optimal value of the individual particles as $pb_i = (pb_{i1}, pb_{i2}, \ldots, pb_{iD})$, the global optimal value of entire population as $gb_i = (gb_{i1}, gb_{i2}, \ldots, gb_{iD})$,and $i = 1, 2, \ldots, m$.Particle optimize and update their location by the following formula:

$$v_{id} = w v_{id} + c_1 rand_1 * (pb_{iD} - x_{id}) + c_2 rand_2 * (gb_{id} - x_{id}) \tag{5}$$
$$x_{id} = x_{id} + v_{id} \tag{6}$$

Among them, c_1 and $c_2$is learning factor, a nonnegative constant, $rand_1$ and $rand_2$ are the random number between the (0, 1). When Particle velocity is large, it has the advantages of approximating global optimal solution more fast, but also has disadvantage of fling away from the optimal solution more possibly [8], to avoid this, this article introduces the adjustment coefficient in the algorithm, (0.1<k<1.0)，Makes the range of particle location not be too big or too small, improves formula (6) :

$$x_{id} = x_{id} + [rand() + k] v_{id} \tag{7}$$

3.1 Cloud model

Cloud model is firstly put forward by professor yi de li in 1995, it has the characteristics of simple, and has certainty and uncertainty at the same time, has stability behind hidden changes, has advantages in optimization of swarm intelligence algorithm [9], the concept of the cloud model can be described by generally expect , entropy and hyper entropy . As shown in the figure below:

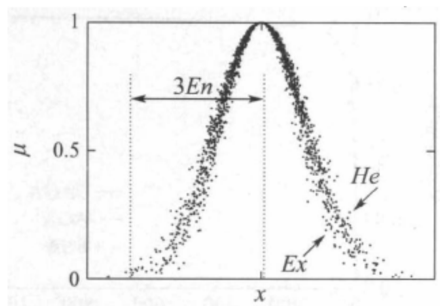


Figure 2 diagram of 3 digital characteristics of the normal cloud model

Cloud generator is the core part of the cloud model, mainly include normal cloud generator and conditional cloud generator. The cloud generator is divided into X condition cloud generator and the Ycondition cloud generator [10].

Algorithm steps of the X condition of cloud generator are as follows:

(1) create a normal random numberE_n', as expectation E_n, as the standard deviation H_e;
(2) create cloud droplets with expectation E_x , E_n'as the standard deviation, X as the normal distribution of random number;
(3) Calculate and determine the degree $y = e^{\frac{-(x-E_x)^2}{2(E_n')^2}}$;
(4) Loop iteration constantly, until to produce N cloud droplets.

3.2 Cloud adaptive particle swarm optimization (CPSO)

Inertia weight factor w is a changeable parameters, means that the largerw is, the stronger global search ability is; While the smaller w is, the stronger local search ability is, to seek for the balance between global search and local search, and improve the performance of the algorithm, choose a suitable inertia factor is very important [11].inertia weight was adjusted to principle of cloud adaptive particle swarm optimization (pso) algorithm the, many experiments was done to find the most appropriate maximum distance d_{max} and the shortest distance d_{min}, maximum weight w_{max} and minimum weight w_{min}, when $d_{ig} > d_{max}$,distance to the current particle inertia weight $w = w_{max}$, and when $d_{ig} < d_{min}$,distance to the current particle inertia weight $w = w_{min}$. When the distance meet $d_{min} < d_{ig} < d_{max}$, according to the nonlinear dynamic adjustment X condition cloud generator inertia weight (d_{ig} denotes t distance between the i particle and the global optimal particlegb), formula is as follows:

$$E_x = w_{max} - \frac{(d_{ig-} d_{min})(w_{max} - w_{min})t}{(d_{max} - d_{min})Maxgen} \quad (8)$$

Maxgen Represents the maximum number of iterations， t represent the current iteration number At the same time set up

$$w = w_{max} - w_{min} * e^{\frac{-(d_{ig} - E_x)^2}{2(E_n')^2}} \quad (9)$$

As a result, the value of inertia weight can dynamically change and achieve the optimal value.

4. OPTIMIZE THE WAVELET NEURAL NETWORK PREDICTION ALGORITHM BASED ON CLOUD PARTICLE SWARM ALGORITHM.

Based on the cloud theory, the particle swarm algorithm, wavelet theory and neural network to build the cloud particle swarm algorithm to optimize the wavelet neural network prediction model, basic steps of the algorithm are as follows:

Step1 initialize parameters of wavelet neural network, the network's input layer neurons of hidden layer and output layer number; use the position of each particle vector to express wavelet neural network and connection weights, scaling factor and shift factor, namely

Among them, denotes the number of hidden layer, denotes particle number.

Step2 initializing parameters of particle swarm optimization (pso), including particle position and velocity of random values ,population size, the number of iterations, learning factors and limit the inertia weight and speed , dimension, the acceleration coefficient, set the distance between ith particle and the global optimal particlegb.

Step3 using the formula (5), (7), (8), (9) to update particle position vector respectively , the velocity vector, the inertia weight, until the end of the iteration, and the value of prediction error is used to determine the value of the particles' fitness, such as formula shown in 10, at last, optimal location of each individual particle $pb$and the entire global optimal position of the populationgb was recorded .

$$f(x) = \sum_{n=1}^{n} |y_i - h_i| \quad (10)$$

Among them, the fitness function was expressed by the prediction error of wavelet neural network, i denotes the prediction of the first node output, j and denotes the first node of the expected output.

Step 4 compare all the fitness value of particles, particles has the best fitness value was obtained .Determine whether satisfy the end condition of algorithm, if does then stop the search, or turn to step 3; eventually integrate the global optimal value into the right values and parameters of wavelet neural network, and calculate the network output.

5. SIMULATION EXPERIMENTS AND ANALYSIS

5.1 Simulation Conditions

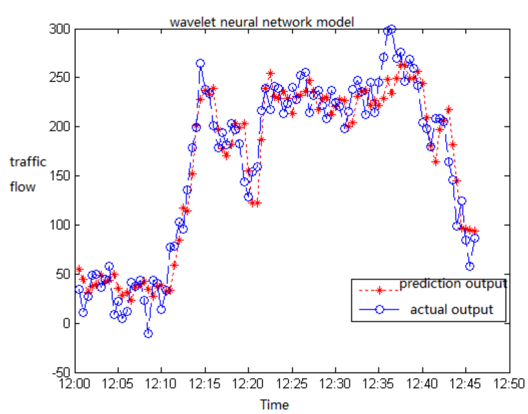
In Matlab2013a environment, the wavelet neural network (WNN) prediction model, the optimized prediction model of wavelet neural network (PSOWNN) and cloud based particle swarm algorithm to optimize wavelet neural network model (CPSOWNN) was used in the same sequence and traffic flow prediction experiments, to verify the effectiveness of above three kinds of models. The experiment uses three layers BP neural network, hidden node number is 6, study probability of 0.01 and 0.01, the training iteration number is 100, the population size of particle swarm optimization (pso) is 60, the largest number of iterations is 100, set accelerated factor $c_1 = c_2 = 1.95$, the inertia weight, $w_{max} = 1.2, w_{min} = 0.6$,,the scope of particle position for [- 5, 5], and speed scope is [-1, 1]. Experiment using the absolute error, mean absolute error and relative error as evaluation error respectively, Input and output data of traffic flow normalized processing is as shown in the following type.

$$x = \frac{x_{i-} x_{min}}{x_{max-} x_{min}} \qquad (11)$$

x is the actual traffic flow data, x_i is the data before normalized, x_{max} and x_{min} denotes the maximum and minimum value.

5.2 Result of the short-term traffic flow prediction and analysis

Simulation data samples is in every 5 minutes for one unit, comes from the regions of Qingdao city , consists of 460 data, the 368 data was stored in the input - test (training samples), another 92 data stored in the output - test (prediction samples). Figure 3, figure 4 and figure 5 is the prediction result of the traffic flow and absolute error results of wavelet neural network model, the optimized wavelet neural network model by the particle swarm algorithm and optimized the wavelet neural network model based on cloud particle swarm algorithm respectively. Average absolute error and relative error of the three prediction models are presented in table 1, using the same number of training sample and forecast sample.



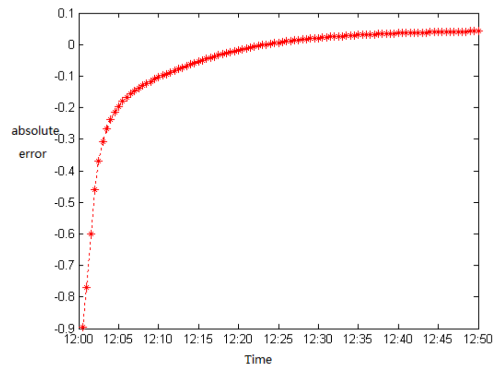


Figure 3 prediction results of wavelet neural network model

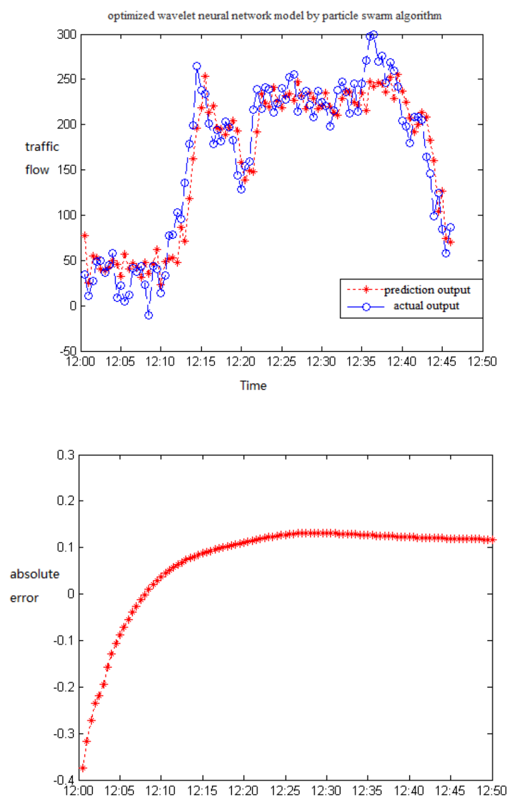


Figure 4 prediction results of optimized wavelet neural network model by particle swarm algorithm

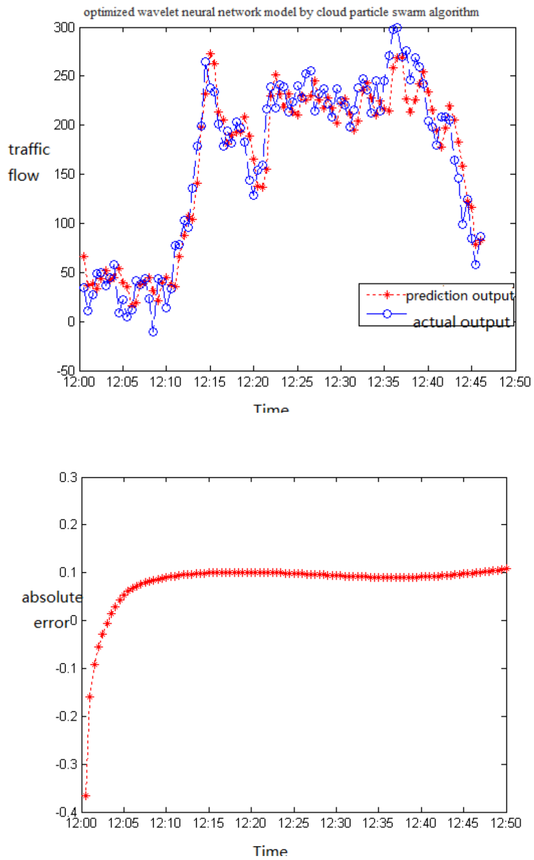


Figure5 prediction results of optimized wavelet neural network model by cloud particle swarm algorithm

Table 1 prediction error of the different training sample

NN Model	SOWNN Model	PSOWNN Model
AE 0.459776	0.372171	0.244689
err 8.43342E-05	2.23969E-05	8.03746E-06

From figure 4, 5 and 6, we can see that prediction results of above models gravely deviates from the actual data and the change trend of traffic flow in the sample, this proves that the wavelet neural network mode has superiority for predicting short-term traffic flow. But compared with the other two models, the optimized wavelet neural network mode by cloud particle swarm algorithm can better simulate the trend of the traffic flow, so CPSOWNN model has better prediction ability than PSOWNN and WNN model.

The table 1 shows that the particles in the best location will not be effected by history optimal location of its own and community, due to the adaptive mutation of PSO algorithm helps avoid to form a convergence effect, with training sample number as 368, prediction accuracy of CPSOWNN model is higher than that of PSOWNN and the WNN model. This result fully verifies the effectiveness of CPSOWNN model.

6. CONCLUSION

In this article, adaptive PSO algorithm based on the principle of cloud is introduced, then optimized wavelet neural network prediction method was introduced based on cloud particle swarm algorithm, to tackle the time varying assumptions underlying the currently used methods, where: 1) the characteristics of current data captured by on road sensors are assumed to be time invariant with respect to those of the historical data which was used to developed short term traffic flow predictors; and 2) the configuration of the on road sensor systems is assumed to be time invariant. By tackling these two time-varying assumptions ,the CPSO is developed by integrating the mechanisms of cloud to a certain extent, the improved model has weaken the disadvantages of wavelet neural network, meantime, improves the prediction performance .Then the model was applied to traffic flow forecast simulation experiment and compared with PSOWNN and WNN model. Results show that the method is PSOWNN model and the WNN model, because the faster the optimized convergence speed of wavelet neural network model, the higher the global search ability of the model was improved, so stronger ability of adapting to real-time traffic flow forecast was obtained. But also model introduced in this article has its shortcoming, so more work should be done to improve it.

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