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Highway Traffic Incident Detection Based on BPNN

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Abstract

Because traffic incident is the main cause of traffic congestion in Highway, traffic incident detection plays an important role in ITS. Based on the professional software VISSIM, we performed an experiment on incident caused by traffic jam to obtain the original simulated data. We offered a way to deal and analyse the traffic prameters, then an updated automatic traffic incident detection method was proposed based on BP neural network. Simulation result shows that the new method has many advantages such as higher detection rate, lower false alarm rate and shorter mean detection time.

Keywords: traffic incident; VISSIM; automatic incident detection; BPNN

1 Introduction of traffic incident detection

1.1 The Importance of traffic incident detection

Traffic incident detection plays a decisive role for being the core and key of the traffic incident management system. The transportation management system which depends largely extent on high efficiency and reliable traffic incident detection technology. Traffic incident detection system can give the fastest and disposal of the incidents on the road, which can reduce casualties and property loss, avoid the second-incident, save energy and shorten the pollution as well as realize the real-time monitoring on traffic incident condition. It also provides data support and real-time control for traffic management department which helps to save time and release traffic jam.

1.2 Category and application of different traffic incident detection method

The highway traffic incident detection method includes manual incident detection (MID) and automatic incident detection (AID). The manual incident detection is the earliest and the most universal method applied to report traffic jam or incident information in diary which. Its main advantages are convenient, direct and efficient, while the disadvantages are follows, such as the need of witness, hard to define the place of congestion and incident, and need the professionals to select and confirm report, therefore the work intensity is high. Taking account of the

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manual incident detection is easy to be influenced by time or weather and taking a long time, the experts in different countries try their best to study and exploit the automatic incident detection in order to make it work all the time and get higher detection rate.

Hence, the application of MID and AID is different. MID is often used in city road while AID is applied in highway and urban expressway[1].

1.3 Evaluation indicators of traffic incident detection algorithm

We usually used three performance indicators which are detection rate（DR）, false alarm rate （FAR） and mean time to detect （MTTD） to assess the performance of AID algorithm[2].

(1) Detection rate（DR）

DR is the ratio between the number of incidents and strategy sum .

$$DR = \frac{incident\ number\ of\ \det ecction}{sum\ of\ incident} \times 100\% \tag{1}$$

(2) False alarm rate（FAR）

FAR is the ratio between the times of false alarm and strategy sum .

$$\mathrm{FA}R = \frac{number\ of\ false\ alarm}{sum\ of\ decision} \times 100\% \tag{2}$$

(3) Mean time to detect（MTTD）

MTTD is the mean time from the incident generation to algorithm detection.

$$MTTD = \frac{1}{n}\sum_{\mathrm{i=1}}^{\mathrm{n}}\left[\mathrm{TI(i)} - \mathrm{AT(i)}\right] \tag{3}$$

Where $TI(i)$ is the actual time of the incident i, $AT(i)$ is the detection time of the incident i, n is the the number of incident.

DR and FAR reflect the effectiveness of AID, while MTTD reflect efficiency. DR and FAR are correlated, reducing FAR can lead the omission factor rising and correspondingly lead the detection rate lowering. The measure to reduce FAR is persistence test, but this measure would increase MTTD, so DR, FAR and MTTD are correlated, it must be synthetically considered in the assessment.

2 Relization of traffic indent detection with neural network

2.1 Theory of BPNN

Neural networks are widely interconnected by a large number of neurons. Because of its learning , multi-input parallel processing, misalignment mapping and fault-tolerant ability, as well as obtaining the auto-adapted ability via the new knowledge, it has been widely used in the pattern recognition, the control optimization and the failure diagnosis.

There are many kinds of neural network, in which BPNN(Back Propagation Neural Network) is one of the most widely used artificial neural networks.

Seen from the structure, BPNN is a typical forward type network according to the training of multilayer feedforward network. BPNN can learn a lot of input-output model mapping relation, without the prior to reveal the mapping relationship of describing mathematical equations. It uses the rules of learning the steepest descent method, through propagation to constantly adjusting the network weights and threshold, make the minimum error square network. The topology structure of BPNN includes input layer, hidden layer and output layer (Figure 1) .

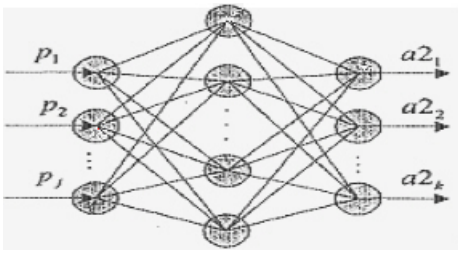

Figure 1. Three-layer feedforward structure of BPNN

BP algorithm is composed of forward calculated and error back-propagation process. In the forward calculated process, the information is transmitted from the input layer to the output one. Each layer only affects the next state. If it cannot obtain the expected output from the output layer, then turn to the back-propagation and make the error signal back along the original connection path. By modifying the weights of each layer, it can make the error signal smallest.

It is proved that a three-hidden layer BP neural network can approach any rational function. So only one hidden layer of BPNN is suffice for the general problem.

2.2 Application of traffic indent detection with neural network

The highway accidents happened on occasional and would have a serious effect on the clear and safety of the transportation on the highroads, such as traffic accidents, fault stopping, goods scattering and so on. When an accident happened, it would lead to one or more driveway be blocked at here, and from here to its upstream, the transportation would be relatively heavy, share increasing, speed deducing, density increasing, while the downstream is opposite. Most incident detection algorithms rest on those transportation features, then analyze the parameters gathered from the transportation detector arranged along the freeway, once the detector find out those features, it would send an incident report.

As the detection algorithm developed till now, it can be classified into four kinds: Pattern Recognition Algorithm, Statistical Algorithm, Catastrophe Theory Algorithm and Neural Network Algorithm.

Traditional incidents detection is that infer, assume and simplify the relations and rules between parameters of traffic flow in theoretical, then simulate situation of traffic flow with Calculate Simulation. Its results compare with the realities which decide whether the mode reflect the deed. In order to simulate the reality of the traffic flow flexible, we spend too much time in discussing, innovation, improvement and inspection. We emphasize modifying expression, augmenting correction terms, modifying parameters, which make modes become more and more complicated, Although modes is more effective, its timeliness and practicability cut down.

Actually, because the mode is infinite dimensional, nolinear, time variant and in high order, and it is a very complicated dynamics system. If we want to infer some kind of regulation to describe the traffic flow, it`s impossible to contain all the features. Owing to the artificial neural network theory is growing up and practical, we can get the regulations from datum, that means its possible to study mode from indirect problems[3].

The neural network start from the real and representational datum of traffic flow, induce the regulations directly. This belongs to the indirect problems, that is the given traffic flow parameters is sample points, and the neural network use them to study and output the approximate features-seeking truth from facts. With the application of the neural network, it`s more easy to build a model, avoid to modify the original mode and describe the regulation after practicing the datum of traffic flow directly. [4-8] This is the advantage of the neural network.

3 System model of traffic incident detection

3.1 Data acquirition and normalization of traffic incident

It carries on the simulation to the transportation incident and gains the orgrin date of the transportation incident by the VISSIM simulation software in this article. The VISSIM is a microscopic, being based on the time-gap and the driving behavior simulation modeling tool, which is developed by German PTV Corporation. It is so effective in appraising the traffic engineering design and the urban planning plan that you can use in the modeling and analyzing

each kind of traffic conditions (traffic lane establishment, transportation constitution, traffic signal, public transportation stand and so on) the municipal transportation and mass transit's movement condition.

VISSIM simulate the characteristics of traffic flow before and after the accident. Its simulation run of the road condition and traffic flow is identical with in current situation. This simulation using parameters with highest quality to guarantee the accuracy of data generated. Using Mat lab during data processing to removes singular points which make the traffic flow value be zero to get the finial data before and after the accident.

This paper carry on the simulation with the professional software --VISSIM. Simulation of each simulation time is 500 seconds per groups and it has a total of 50 groups. The simulation data is obtained by using Matlab for processing.

In order to improve the ratio of test and keep the integrity of information, selecting different blocking of transportation message of upper-lower besides. This means to choose upstream velocity and downstream share as two information contents.

Normalized handing of data must be finished before signal processing. The traffic time-series data are normalized[9] by dividing them by the average of the highest two values in each series as

$$x_i = \frac{2 * x_i}{\overline{x}_1 + \overline{x}_2} \tag{4}$$

Where $\overline{x}_1$ and $\overline{x}_2$ represents the first and the second maximum of the data series.

Normalization reduces the significance of magnitude in the pattern recognition process and the undesirable domination of a single large value. Patterns are distinguished primarily on the basis of their shape and form and not on the basis of magnitude. As a result, the normalization technique also eliminates the need for re-calibration whenever the flow condition changes. Flow variations caused by daily rush time traffic, weather conditions, geometry, and other situations can therefore be handled automatically and transparently.

To demonstrate this, we take the data decomposition of a couple of the exist and non-exist incident as an example. After db2 wavelet two-level-decomposition of the normalized data, we get the second approximate coefficients. In which tca_0 is upstream velocity approximate coefficient of exist incident, bca_0 is downstream occupancy approximate coefficient of exist incident, tca_1 is upstream velocity approximate coefficient of non-exist incident, bca_1 is downstream approximate coefficient of non-exist incident.

So we get two vectors:

$$p_{10} = [tca_0, bca_0] \text{ and } p_{11} = [tca_1, bca_1] \tag{5}$$

Thus, wavelet analysis of data processing is finished.

Let $p_1 = [p_{10}^T, p_{11}^T]$, where p_1 is a couple of input vector and its corresponding output vector is $c_1 = [0,1]$ in which 0 means non-exist incident and 1 means exist incident. similarly, we can get the other 49 couples of input vectors. These input vectors form the input matrix $P = [p_1, p_2, \Lambda\ , p_{50}]$ and its ouput matrix $C = [c_1, c_2, \Lambda\ , c_{50}]$.

3.2 Detection model based of BPNN

The diagram of testing system is shown in Figure 2.

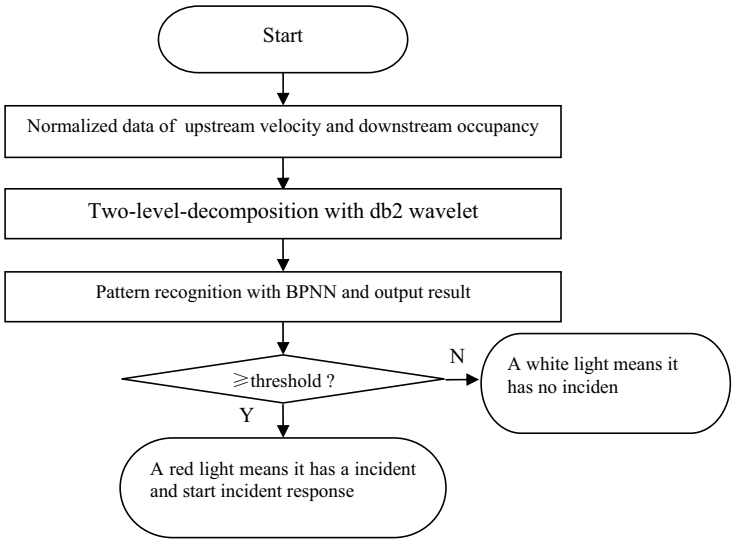

Figure 2. Diagram of traffic incident detection system

The framework of the network is 20×23×1 , which is the network compose with Input Layer ,Hidden Layer , Output Layer .Among the Input Layer ,there are 20 points .In Hidden Layer ,there are 23 points .In Output Layer ,there are 1 point .

a) Input layer

The 20 points in input layer represent those datum . Therefore, input the 10 numerical of without incident rate under low-frequency coefficients in upstream and downstream and the V of low-frequency coefficients of share as a group, there are 40 group normal data for studying . At the same time, input the 10 numerical of incidents condition of low-frequency coefficients of speed in upstream and the 10 numerical of low-frequency coefficients of share in downstream as a group, here are 40 group normal data for studying . So there are 80 group datum in total to input defined as input matrix $P = [p_1, p_2, \Lambda\ , p_{40}]$ and its ouput matrix $C = [c_1, c_2, \Lambda\ , c_{40}]$.

b) Hidden Layer

In BP network, the number of hidden nodes is very important . It not only has a influence on building a neural network model, and is the direct reason of training "after fitting", but there is no scientific theory and method to determine the universal. Ensuring the enough high network performance and generalization ability, the most basic principles of determining the number of hidden layer is, on the premise of compact structure, taking as little as possible hidden layer nodes. After constant testing, when the hidden nodes is 23,we get good results.

c) Output Layer

There is only one node in output layer, it divides into two states. 40 datum without incident outputs “0”. If there are some incidents happen, it outputs “1”. Through programming in Matlab, from neural network training we draws the following results. Error curve is shown in figure 3.

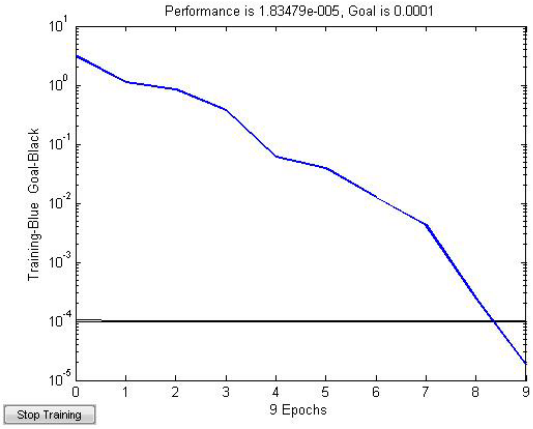

Figure 3. Error curve diagram of training

TRAINLM, Epoch 0/500, MSE 3.18675/0.0001, Gradient 27177.5/1e-010
TRAINLM, Epoch 9/500, MSE 1.83479e-005/0.0001, Gradient 18.789/1e-010
TRAINLM, Performance goal met.

After 9 iterative, it has met the error demand and has a fast convergence speed.

From the output resulting of many testing, the output of the non-incidents is mainly from -0.03 to 0.4 and the output of the incidents is above 0.889. It shows that the model's discrimination ability is good, so we set discriminant threshold in this incident equal to 0.85. The higher threshold detection model is also based on good performance.

3.3 Union programming of LabVIEW and Matlab

LabVIEW is t established in the graph data stream programming language G language which easy to use, greatly simplified the process control and the development of testing software. Matlab has become mathematical computation tool aspect standard in fact, by its formidable science computation function, the massive stable reliable algorithm storehouse. Both may and may realize the complex data processing and the algorithm through the two's union programming using the LabVIEW splendid contact surface design and the direct-viewing demonstration effect through Matlab realizes. LabVIEW and the Matlab union programming uses the Script node in LabVIEW software's Matlab to realizes LabVIEW and the Matlab seamless engagement.

Using "Matlab Script Node" provided in LabVIEW, we can realize union programming with the two languages. There are two screen to show upstream speed respectively and downstream share values. Numbers can also be displayed at the top of the numerical screen . WARNING lights used to shou whether there are traffic incidents. If no incidents, the white light brightened, else the red light brightened. The front panels are shown in figure 4 and figure 5.

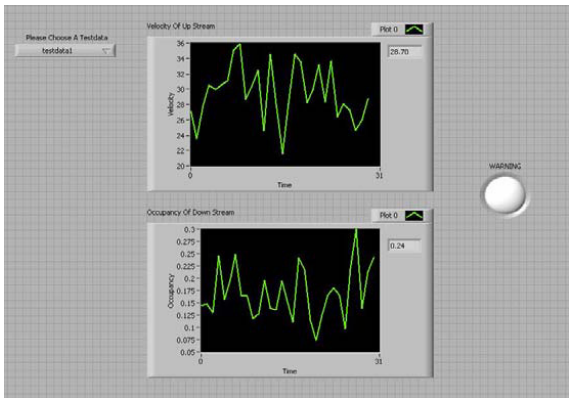

Figure 4. Display of the front panel when it has no incident

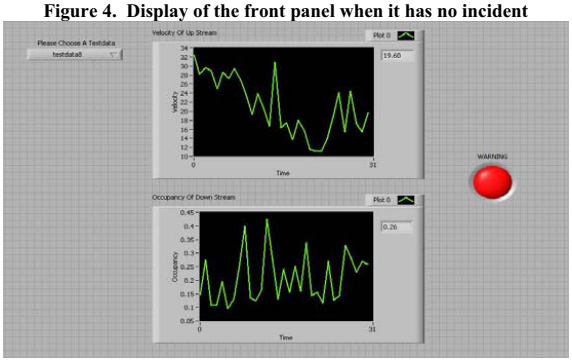

Figure 5. Display of the front panel when it has an incident

3.4 Test and evaluation of detection system

The traffic incident detection system designed in this paper can use in real incident detection. Thinking about the difficult of getting real-time data, in here we will use 20 group data which is got by simulation software VISSIM and has pretreatment in our test. Firstly, we set 20 groups of input data to read one by one, then input them in the detection model and run the program. Finally we can get a result shown in table 1.

Tab.1 Results of neural network detection

Group No.	1	2	3	4	5	6	7	8	9	10
Result	-0.0248	0.2348	-0.0962	0.9974	0.2299	0.9691	0.0020	0.9987	-0.0084	0.9638
Group No.	11	12	13	14	15	16	17	18	19	20
Result	0.3069	1.1182	-0.0290	1.2045	0.4018	2.3057	0.2863	0.8888	0.2399	0.9198

These 20 groups of test data are arranged according to the non-incident and incident. By comparing these results, we found that group 2 should be an incident but it is not detected and its output is only 0.2348, which have a obvious error to the standard value of 1. Then we listed the test results and obtained the detection evaluating indicators, as shown in table 2.

Tab.2 Results of evaluating indicators analysis

Detection model	DR	FAR	MTTD(s)
BPNN AID	95%	5.0%	0.0283

4 Conclusions

Traffic incident detection algorithm is very important to the implementation of ITS and how to work out a more efficient algorithm is a potential subject.. This article hopes to continue research in this area and we also believe that our traffic incident detection system have a great impact on the future development of ITS.

However, due to the limited time and energy and money, we adopted the data source from the simulation software VISSIM instead of field data. The system in actual use may have certain deviation.

(1) All the simulated data we used is the incidents happened in outer lane. There is no data about center lane or surpass lane.

(2) The traffic incident simulated is the congestion caused by the vehicles' broke-down and does not involve other traffic incident just like collisions.

But seen from the effect of traffic incident imposing on traffic stream, the results of different incidents are similar. So the traffic incident simulated by simulation software has a good representativeness.

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