Road Traffic Flow control model with the slope of the change rate

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Abstract: Real-time, accurate and efficiency short term traffic flow prediction is one of the key technologies to realize traffic flow guidance and traffic control, which has being widely concerned in the domain of ITS(Intelligent Transport system) during recent years. Through the study of the existing traffic flow prediction model, road traffic flow control model with the slope of the change rate is proposed. The model can find out abnormal point from the traffic flow time series by use of the slope change rate, and it can analyzed this trend of traffic flow changes, thus arrived control purposes of traffic flow. The emulation results indicate that the algorithm is suitable for road traffic flow peak control problem and could be effective measurement for road traffic flow control.

Key-Words: Traffic engineering, traffic flow, slop, change rate, time series.

1 Introduction

Traffic jams in urban have attracted widespread attention in a global, with the development of socio-economic and transport industry [1-2]. Particularly in China, car ownership has reached hundred million vehicles [3], but Chinese road construction now fall behind development of the automotive industry, traffic congestion has become a widespread social phenomenon in China's Beijing, Shanghai, Guangzhou and other cities, so it has become people's focus.

To some extent, traffic congestion has become important problem in economic development and social stability, however, limited land and restricted economic and other factors which are impossible to achieve relatively satisfactory road construction mileage [4-5]. Therefore, the use of modern information technology and data analysis techniques to improve transportation efficiency and improve the traffic capacity of the road network, it has become to solve this problem the only way to road congestion under the existing conditions.

Current traffic flow prediction methods can be divided into four categories [6]. It mainly includes the traditional methods based on statistical theory, the method based on neural network, the method based on of nonlinear theory and the method based on hybrid technology. Traditional theoretical predictions include: the historical average model, regression analysis, time series models, Kalman filter model and markov etc [7]，however, these methods model is relatively simple, and the prediction accuracy is poor, although it can solve the problem of changing the traffic flow at different times, but it is poor deal for unexpected traffic flow and other special circumstances. Artificial neural network technology was born in the 1940s, it is used for long-term traffic flow prediction by Chin in1992, Dougherly and clark, who respectively used neural network technology for short-term traffic flow forecasting in1993 and 1994 [8]. The emergence of neural network algorithm get rid of the trouble to establish a precise mathematical model for the study of work which opened up a new way of thinking, However, accurate prediction of neural networks is based on a large number of historical training or unknown data, the amount of data train and the length of training time, which determines the accuracy of the model prediction, therefore, it is predicted to no historical data, there will be a big predictive error. Nonlinear prediction mainly in chaos theory [9-10], dissipative structure theory, self-organization theory and other theories as theoretical foundation, which uses the concept of chaotic attractor, fractal concept phase space reconstruction methods to build predictive models, however, this model includes many parameters, and not easy to determine, it makes nonlinear algorithms in prediction accuracy that is not easy to control and reduce the usefulness of the nonlinear algorithm. Hybrid algorithm is based on the advantages of various algorithms [11-12], which take complementary advantages principle and combine the advantages of different algorithms, and make up for the lack of a single algorithm, the type of prediction algorithm has been widely applied, however, this embodiment is relatively complex to structure of the algorithm, the algorithm is more difficult to fusion in the practical application, there are still many problems.

Uses traffic data to predict traffic patterns, as a research direction, is studied by a lot of scholars. The given traffic prediction models become inaccurate under partially missing data. Missing data indicates the unavailability of traffic data for a certain period of time in part of a transportation network due to sensor malfunction or noise-contaminated data. This problem frequently occurs in transportation networks [13-15]. Many studies address the issue of traffic prediction with partially missing traffic data. For instance, van Lint et al. [23] presented a neural network for travel time prediction under missing traffic data. Sun et al. [16-17] introduced a Bayesian method to forecast traffic flows where a certain period of historical data is missing for some links of the transportation network. The missing portion of historical traffic data is approximated by using a Gaussian mixture model. Moreover, other statistical and probabilistic methods are used to address the missing traffic data problem [18-22]. Therefore, the problem of short-term traffic flow prediction based on completely unavailable traffic data in some links due to lack of sensors in the network is an open challenging problem.

In this paper, traffic flow prediction model with abnormal data mining algorithm have been proposed in current research methods. Model algorithm based on the linear slope, it makes use of the slope calculation principle and the technology of data mining, to found out the abnormal data in traffic flow, it uses these abnormal points as traffic warning basis, and help the traffic management departments to make reasonable decision, and guide the car pass smoothly, and avoid congestion phenomenon.

The rest of this paper is organized as follows: Section 2 describes the overall structure of early warning model based on data mining technology. Section 3 presents abnormal data mining algorithms based on the slope calculation principles, as well as early warning processing approach. Section 4 introduces algorithm simulation and prediction processing simulation by use of real data. Section 5 summarizes the paper and outlines the application of the model algorithm.

2 Problem Formulation

In order to realize the traffic flow prediction, it can predict the road traffic conditions, and make reasonable traffic guidance, and avoid the occurrence of traffic jams, the early warning control model of traffic was be presented. Realization diagram of the model are as follows:

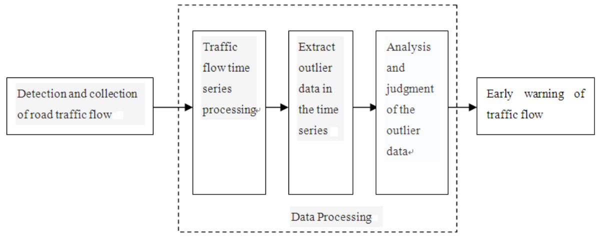


Fig.1 Processing model of traffic flow based on abnormal data mining

2.1 Detection and collection of road traffic flow

It will be determined the warning effect to sources of traffic data in traffic flow warning, therefore in this paper, which used traffic flow detector acquisition technology based on microwave detector RTMS (Remote Traffic Microwave Sensor) [7], it can achieve traffic flow data collection. Figure 2 as follows:

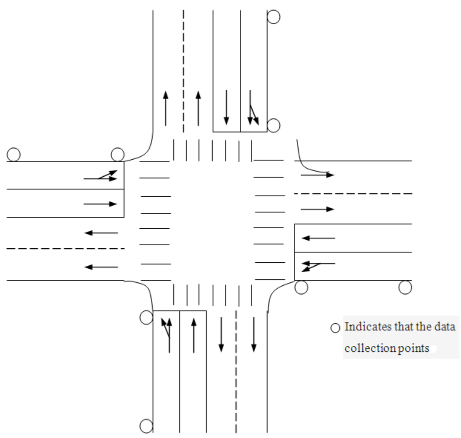


Fig.2 Schematic of traffic flow data collection

As can be seen from Fig.2, this road is a crossroads, Detector is placed in the four corners of the road, two detectors separated by 150 meters on each road, Within the prescribed time, the collection data detected by the two detectors on each road, after ever collection, the two data were be subtracted, and returned a numeric result, this result was divide by Road traffic capacity, and returned the result which named the occupancy rate of the road. The collected data according to S_i (d_i, t_i) for storage, Where S_i is the acquisition time sequence group in i roads and i time, d_i means that the road occupancy rate, t_i is collection point in time.

2.2Traffic flow data processing

Time series of traffic flow will be calculated by use of the slope of the principle for abnormal data mining, the abnormal points from the abnormal data were be analyzed, it can determine the road traffic situation which will occur changed. From the analysis of results, this changed was be sent to confident control department. Traffic management departments will use the relevant processing mode, such as traffic lights alternating time changes, and traffic electronic screen guidance, and traffic broadcast, and traffic grooming, these ways will be used to change the route and prevent traffic jams. As shown in figure 3:

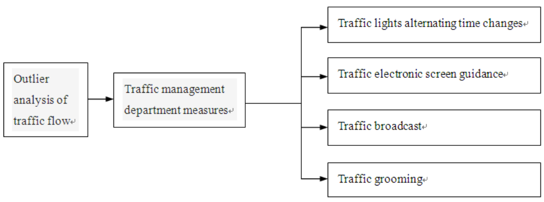


Fig.3 Traffic warning handling diagram

3 Traffic Flow Data Processing and Alert Processing

In order to find the traffic flow abnormal data, road traffic flow control model with the slope of the change rate is proposed in this paper. The algorithm included that collect the road traffic flow data and determined the data point in the time axis and computed the slope of the line passing through each pair of adjacent data points.

Definitions3.1: Any three consecutive points are $s_{i-1}$and s_i and s_{i+1} in traffic flow time series, k_i is the slope the straight line $s_{i-1}s_i$, k_{i+1} is the slope the straight line $s_{i-1}s_i$, this two straight lines directions are different,if $k_i \cdot k_{i+1} < 0$. This two straight lines direction are same, if $k_i \cdot k_{i+1} > 0$ [24].

Corollary3.1: Given the slop change threshold of two straight lines with m_1, if his two straight lines directions are different. There is no abnormal data, if $|k_{i+1} - k_i| < m_1$. There is abnormal data, if $|k_{i+1} - k_i| > m_1$, and s_i is considered abnormal point.

Corollary3.2: Given the slop change threshold of two straight lines with m_2, if his two straight lines directions are same. There is no abnormal data, if $|k_{i+1}| < m_2$. There is abnormal data, if $|k_{i+1}| > m_2$, and s_i is considered abnormal point.

Definition 3.1 is proved:

Given three consecutive point with s_{i-1} and s_i and s_{i+1} in traffic flow series times, their axis are (x_{i-1}, y_{i-1}) and (x_i, y_i) and (x_{i+1}, y_{i+1}) in the coordinate axes, k_i is the slope the straight line $s_{i-1}s_i$, k_{i+1} is the slope the straight line $s_{i-1}s_i$. The following four cases will be discussed, because the two straight lines which can be constructed by three consecutive points have different direction.

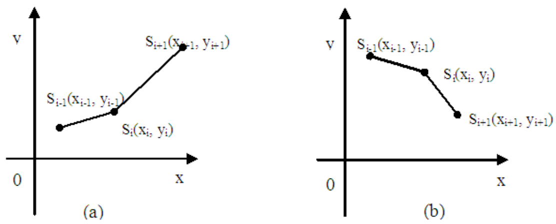


Fig4. The two straight lines have same direction

Case 1: If $x_{i-1}<x_i$, $y_{i-1}<y_i$ and $x_i<x_{i+1}$, $y_i<y_{i+1}$, the establishment of the formula (1):

$$K_i = \frac{y_i - y_{i-1}}{x_i - x_{i-1}} > 0, \quad K_{i+1} = \frac{y_i - y_{i+1}}{x_i - x_{i+1}} > 0 \quad (1)$$

According to the principle of slope, K_i>0 and K_{i+1}>0, as can be seen from fig.4(a), Two lines have the same directions, and their directions are upward and rightward.

Case 2: If $x_{i-1}<x_i$, $y_{i-1}>y_i$ and $x_i<x_{i+1}$, $y_i>y_{i+1}$, the establishment of the formula (2):

$$K_i = \frac{y_i - y_{i-1}}{x_i - x_{i-1}} < 0, \quad K_{i+1} = \frac{y_i - y_{i+1}}{x_i - x_{i+1}} < 0 \quad (2)$$

According to the principle of slope, K_i<0 and K_{i+1}<0, as can be seen from fig.4 (b), Two lines have the same directions, and their directions are up down and rightward.

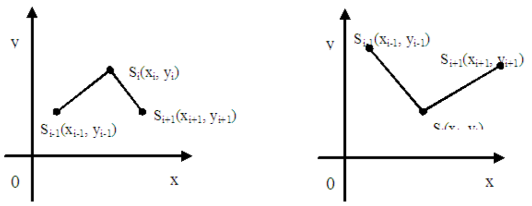


Fig.5 the two straight lines have different direction

Case 3: If $x_{i-1}<x_i$, $y_{i-1}<y_i$ and $x_i<x_{i+1}$, $y_i>y_{i+1}$, the establishment of the formula (3):

$$K_i=\frac{y_i-y_{i-1}}{x_i-x_{i-1}}>0,\quad K_{i+1}=\frac{y_i-y_{i+1}}{x_i-x_{i+1}}<0 \qquad (3)$$

According to the principle of slope, $K_i>0$ and $K_{i+1}<0$, as can be seen from fig.5 (a), lines $S_{i-1}S_i$ direction is upward and rightward, lines S_iS_{i+1} direction is up down and rightward.

Case 4: If $x_{i-1}<x_i$, $y_{i-1}>y_i$ and $x_i<x_{i+1}$, $y_i<y_{i+1}$, the establishment of the formula (4):

$$K_i=\frac{y_i-y_{i-1}}{x_i-x_{i-1}}>0,\quad K_{i+1}=\frac{y_i-y_{i+1}}{x_i-x_{i+1}}<0 \qquad (4)$$

According to the principle of slope, $K_i<0$ and $K_{i+1}>0$, as can be seen from fig.5 (b), lines $S_{i-1}S_i$ direction is up down and rightward, lines S_iS_{i+1} direction is upward and rightward.

Corollary3. 1 is proved：

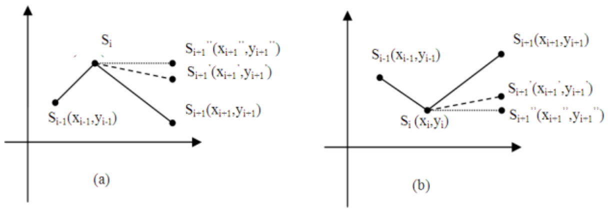


Fig.6 Abnormal point between the different direction the line

(1) Assuming the two lines have different direction, and meeting the following requirements $x_{i-1}<x_i$, $y_{i-1}<y_i$ and $x_i<x_{i+1}$, $y_i>y_{i+1}$. Let S_{i+1}' and S_{i+1}'' are two point in coordinate axis，their coordinate are (x_{i+1}',y_{i+1}') and (x_{i+1}'',y_{i+1}''), and meeting the following requirements $x_{i+1}= x_{i+1}'= x_{i+1}''>x_i, y_{i+1}> y_{i+1}'> y_{i+1}''>y_i$. As can be seen from Fig.6 (a), the line slop of $S_iS_{i+1}$and S_iS_{i+1}'and S_iS_{i+1} can be given:

$$K_{i+1}=\frac{y_{i+1}-y_i}{x_{i+1}-x_i},\quad K_{i+1}'=\frac{y_{i+1}'-y_i}{x_{i+1}'-x_i},\quad K_{i+1}''=\frac{y_{i+1}''-y_i}{x_{i+1}''-x_i} \qquad (5)$$

According to the case 3 and the slop theory, there are the following relations

$$|K_{i+1}-K_i|>|K_{i+1}'-K_i|>|K_{i+1}''-K_i| \qquad (6)$$

As can be seen from formula (6), the slop change rate of S_iS_{i+1} and $S_{i-1}S_i$ is largest than other the slop change rate. Set the threshold is m_1 in the slop change rate, if the slop change rate is bigger than m_1, there is abnormal data, and s_i is considered abnormal point.

(2) Assuming the two lines have different direction, and meeting the following requirements $x_{i-1}<x_i$, $y_{i-1}>y_i$ and $x_i<x_{i+1}$, $y_i<y_{i+1}$. Let S_{i+1}' and S_{i+1}'' are two point in coordinate axis，their coordinate are (x_{i+1}',y_{i+1}') and (x_{i+1}'',y_{i+1}''), and meeting the following requirements $x_{i+1}= x_{i+1}'= x_{i+1}''>x_i, y_{i+1}> y_{i+1}'> y_{i+1}''>y_i$, As can be seen from Fig.6 (b), the line slop of $S_iS_{i+1}$and S_iS_{i+1}'and S_iS_{i+1} can be given:

$$K_{i+1}=\frac{y_{i+1}-y_i}{x_{i+1}-x_i},\quad K_{i+1}'=\frac{y_{i+1}'-y_i}{x_{i+1}'-x_i},\quad K_{i+1}''=\frac{y_{i+1}''-y_i}{x_{i+1}''-x_i} \qquad (7)$$

According to the case 4 and the slop theory, there are the following relations

$$|K_{i+1}-K_i|>|K_{i+1}'-K_i|>|K_{i+1}''-K_i| \qquad (8)$$

As can be seen from formula (8), the slop change rate of S_iS_{i+1} and $S_{i-1}S_i$ is largest than other the slop change rate. Set the threshold is m_1 in the slop change rate, if the slop change rate is bigger than m_1, there is abnormal data, and s_i is considered abnormal point.

Corollary 3.2 is proved：

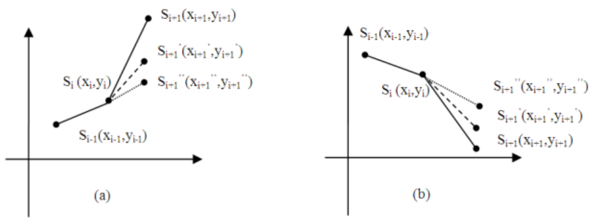


Fig.7 Abnormal point between the different direction the line

(1) the two lines have same direction, and meeting the following requirements $x_{i-1}<x_i$, $y_{i-1}<y_i$ and $x_i<x_{i+1}$, $y_i<y_{i+1}$. Let S_{i+1}' and S_{i+1}'' are two point in coordinate axis, their coordinate are (x_{i+1}',y_{i+1}') and (x_{i+1}'',y_{i+1}''), and meeting the following requirements $x_{i+1}= x_{i+1}' = x_{i+1}''>x_i$,$y_{i+1}> y_{i+1}'> y_{i+1}''>y_i$. As can be seen from Fig.7 (a), the line slop of $S_iS_{i+1}$and S_iS_{i+1}'and S_iS_{i+1} can be given:

$$K_{i+1}=\frac{y_{i+1}-y_i}{x_{i+1}-x_i},\quad K_{i+1}'=\frac{y_{i+1}'-y_i}{x_{i+1}'-x_i},\quad K_{i+1}''=\frac{y_{i+1}''-y_i}{x_{i+1}''-x_i} \quad (9)$$

According to the case 3 and the slop theory, there are the following relations

$$|K_{i+1}|>|K_{i+1}'|>|K_{i+1}''| \quad (10)$$

As can be seen from formula (10), the slop change rate of S_iS_{i+1} and $S_{i-1}S_i$ is largest than other the slop change rate. Set the threshold is m_2 in the slop change rate, if the slop change rate is bigger than m_2, there is abnormal data, and s_i is considered abnormal point.

(2) Assuming the two lines have same direction, and meeting the following requirements $x_{i-1}<x_i$, $y_{i-1}>y_i$ and $x_i<x_{i+1}$, $y_i>y_{i+1}$. Let $S_{i+1}'$and $S_{i+1}''$are two point in coordinate axis, their coordinate are (x_{i+1}',y_{i+1}') and (x_{i+1}'',y_{i+1}''), and meeting the following requirements $x_{i+1}= x_{i+1}'= x_{i+1}''>x_i$,$y_{i+1}< y_{i+1}'< y_{i+1}''<y_i$, As can be seen from Fig.7 (b), the line slop of $S_iS_{i+1}$and S_iS_{i+1}'and S_iS_{i+1} can be given:

$$K_{i+1}=\frac{y_{i+1}-y_i}{x_{i+1}-x_i},\quad K_{i+1}'=\frac{y_{i+1}'-y_i}{x_{i+1}'-x_i},\quad K_{i+1}''=\frac{y_{i+1}''-y_i}{x_{i+1}''-x_i} \quad (11)$$

According to the case 4 and the slop theory, there are the following relations

$$|K_{i+1}|>|K_{i+1}'|>|K_{i+1}''| \quad (12)$$

As can be seen from formula (12), the slop change rate of S_iS_{i+1} and $S_{i-1}S_i$ is largest than other the slop change rate. Set the threshold is m_2 in the slop change rate, if the slop change rate is bigger than m_2, there is abnormal data, and si is considered abnormal point.

3.2 Algorithm and program of traffic flow abnormal data mining

According to the above principle, the traffic flows sets S= {S_1,S_2,…S_n} and the slop sets K= {K_1,K_2…K_n} can be calculated and decided as follows. Where S1=(d_1,t_1) ,S_2= (d_2,t_2), Sn= (d_n,t_n), S_n is data point, d_n is traffic flow value, t_n is a collection point in time, K_n is a slope of linear which can be constructed by continuous two points.

(1) If $k_i>0$,$k_{i+1}>0$ and $k_i\cdot k_{i+1}>0$,$|k_{i+1}-k_i|>m_1$, there is abnormal data, and s_i is considered abnormal point, this abnormal point s_i means traffic flows continue to show signs of improvement.

(2) If $k_i<0$,$k_{i+1}<0$ and $k_i\cdot k_{i+1}>0$,$|k_{i+1}-k_i|>m_1$, there is abnormal data, and s_i is considered abnormal point, this abnormal point s_i means traffic flow continue to show signs of decrease.

(3) If $k_i>0$,$k_{i+1}<0$ and $k_i\cdot k_{i+1}<0$,$|k_{i+1}|>m_2$, there is abnormal data, and s_i is considered abnormal point, this abnormal point s_i means the traffic lights have changed from large to small.

(4) If $k_i<0$,$k_{i+1}>0$ and $k_i\cdot k_{i+1}<0$,$|k_{i+1}|>m_2$, there is abnormal data, and s_i is considered abnormal point, this abnormal point s_i means the traffic lights have changed from small to large.

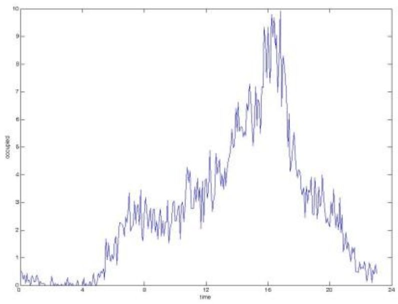
In order to achieve the exception processing of traffic flow, set an array SN_1 which storage abnormal point of traffic flow and include these point of continues to rise or change from small to large, set an array SN_2 storage abnormal points of traffic flow and include these points of continues to falling or from large to small.

3.3 Outlier identification and early warning

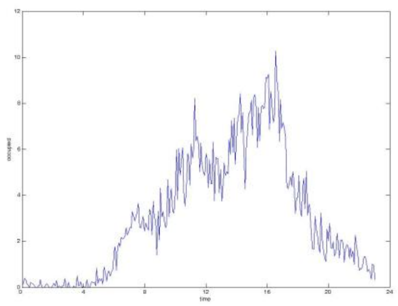
Array SN_1 and SN_2 is analyzed, to determine the current road conditions, according to the result of processing, and the decision made by the traffic administration with the abnormal point processing results, and reduce road congestion. For realized traffic flow data processing and proved experiment simulation testing results, there is an assuming condition that these Measures can be effectively reduced 30% in large traffic flow, these measures include light time changes and the traffic police guidance and electronic screen guidance and traffic radio guidance.

4 Experimental Emulation.

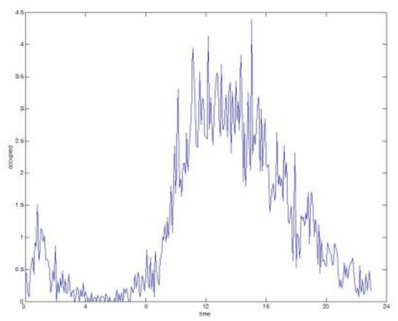
In order to demonstrate the effectiveness of the algorithm model, this model used in traffic data from the university of Minnesota Duluth (http: //www. d.u mn. edu/tdrl/index.htm). Their traffic data research laboratory depends on the traffic management center of Minnesota, and by more than 5000 toroidal coil detector to collect all the year round, and the data stored in the "traffic." format. This article from http://www.d.jumn.edu /tdrl/traffic/ download the data, and we used the software extract the data to analysis, and obtained the data of traffic flow data. We have adopted data on October 1, 2013, on September 20, on September 4, and have stimulated by use of the MATLAB software. Experiments of the computer is a Pentium (R) Dual - core CPUE5300 2.6 GHZ, 1.98 GB of memory, the experiment is stimulated by R2007b MATLAB software.



(a)



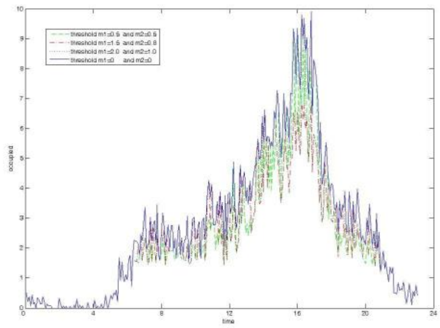
(b)



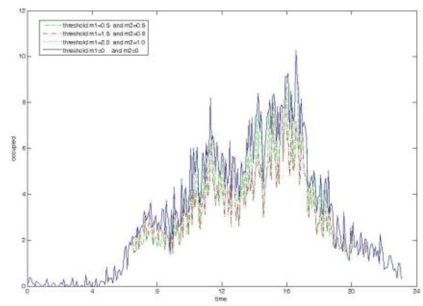
(c)

Fig.8 Traffic flow: (a) Traffic flow on October 1, (b) Traffic flow on September 20, (c) Traffic flow on September 4.

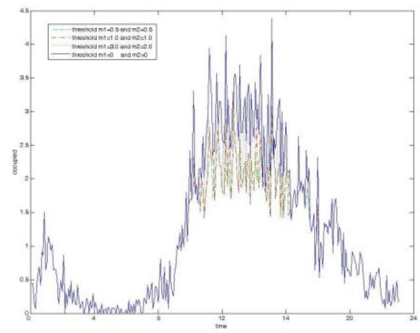
Can be seen from the figure 8, on October 1st, September 20, September 4, road traffic flow is small at 0:00-7:00 PM and 8 PM - 24:00, it shows that the capacity of road is good. At 11:00-16:00, Traffic reaches a peak, road traffic flow is larger. In this period of time, the road traffic flows is high, the capacity of road is poor, and it is easy to cause the road congestion.



(a)



(b)



(c)

Fig.9 Different slope gradient threshold of road traffic stream processing: (a) Traffic flow process on October 1st, (b) Traffic flow process September 20, (c) Traffic flow process September 4.

To test and verify the feasibility of the algorithm, Traffic flow time series to be processed by use of the slope gradient algorithm principle of time series and different slope gradient threshold, as can see from figure 9 (a) and (b), the early warning and control effect of traffic flow time series depends on the threshold, if the threshold is large, the warning and control effect is better at rush hour. If the threshold is small, the warning and control effect is worse at rush hour. But if the threshold is set too high, traffic flow control effect will decline, the reason was abnormal data points of the traffic flow time series were difficult to find by use of the principle of the slope change rate , and unable to realize the early warning and control of traffic flow. As you can see from figure 9 (c), for the low traffic flow on 1 October peak, warning threshold set a small traffic flow control effect is better than the threshold value set. That this algorithm is suitable for the peak early warning and control of traffic flow in the threshold setting is opposite bigger, to the low peak early warning and control of traffic flow in the threshold value set is relatively small. As can seen from figure 9 (c), for traffic flow peak is the low on 1 October, warning threshold is set small to control the effect of traffic flow better than the threshold value is set large. This means this algorithm is suitable for the large traffic flow peak, so if the early traffic flow peak is large, the threshold should be set large, the warning and control effect of traffic flows is better. If the early traffic flow peak is small, the threshold should be set small, the warning and control effect of traffic flows is better.

In short, the advantages of this algorithm does not rely on historical data and the size of the amount data, these data can be real-time collection, real-time processing and real-time analysis, this algorithm reduces the complexity of road traffic flow control.

5 Conclusions

Early warning and control algorithm of traffic flow based on the slope change, it can analyzed abnormal points of traffic flow by use of the straight slope which was construct adjacent data points change, so as to take appropriate control measures and avoid road congestion. Experiments verify the algorithm, in different peak value of traffic flow it should be set different threshold, in order to realize the warning and control of traffic flow.

The goal of this work was to develop a highly accurate method for traffic prediction and control. That goal was clearly achieved by this effort. It can solve the traffic jams in real time, and make the road traffic which is clear. The algorithm is feasible in traffic flow abnormal data mining, it has some value. But it can be seen from this paper, algorithm of the key is set the threshold, the threshold value determines the accuracy of the prediction and control, it will be discussed in the subsequent paper.

Acknowledgements

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