Phantom Traffic Jam Based on MATLAB

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Abstract. In recent years, many cities have formed a complete modern transportation system, but the phenomenon of “phantom traffic jam” is also frequent, the reason of which has been concerned by people. At present, much research has analyzed this phenomenon, but there are still many questions about its occurrence. Therefore, this paper makes an in-depth study and analysis of the phenomenon of “phantom traffic jam”, it can be found that the causes of this phenomenon are the bad driving habits of drivers and unreasonable road planning. In view of this situation, this paper adopts MATLAB as the analysis tool, and establishes a MATLAB traffic congestion prediction model according to the main characteristics of the phenomenon of “phantom traffic jam”. The occurrence mechanism of the phenomenon of “phantom traffic jam” has been combined and it can control the existing traffic network intelligently. According to different congestion conditions, the traffic congestion prediction model is tested separately in the form of secondary classification. It can be found that the accuracy rate of the prediction system in this paper reaches more than 90% from the test results. Therefore, the model can meet the current requirement of traffic congestion prediction.

Keywords: Phantom Traffic Jam, Prediction Model, Traffic Control System

1. Introduction
Traffic in big cities is always a headache and people have adapted to the predictable morning and evening rush hours [1]. But the sudden traffic jams are still making people crazy. In the absence of accidents or lane closures due to construction, the efficiency of vehicle ground traffic suddenly drops and even the entire road network is paralyzed. After a period, the traffic flows smoothly again without any symptoms, as if nothing had happened [2][3]. This inexplicable congestion phenomenon is called “phantom traffic jam” by traffic experts [4].

According to some scholars, “phantom traffic jam” is irregular in space and time, but any traffic jam has its roots. In generally, the root cause of traffic congestion is that urban roads cannot meet the demand of vehicles [5][6]. In technically speaking, road intersections and bottleneck areas are the common ground of traffic congestion, and there are certain rules to follow. This phenomenon is more likely to occur when the road is very busy, and the traffic flow is near saturation [7].

This paper makes an in-depth study on the characteristics of the phenomenon of “phantom traffic jam”. Through investigation, it is found that the phenomenon is more likely to occur in large cities [8].
There is no unified conclusion on the causes of this phenomenon in academic circles [9]. This paper argues that this phenomenon is a chain reaction, in which the bad driving behavior of a single driver is amplified by a complex traffic network. To further study it, MATLAB software was used to build the traffic congestion prediction model. “phantom traffic jam” recreates via simulation, then, according to the characteristics of the phenomenon of “phantom traffic jam”, the prediction method of the model is optimized and improved. In the simulation of congestion and non-congestion conditions, the prediction model can quickly calculate the prediction results, and the accuracy rate exceeds 90%. To sum up, the research in this paper has achieved ideal results and played a reference role in urban traffic road planning and design.

2. MATLAB and Phantom Traffic Jam

2.1. Introduction to MATLAB
MATLAB is a powerful technical application software, it has a powerful technology computing, graphics processing, and the characteristics of openness. MATLAB language is a high-level programming language widely used in image signal processing, electronic system engineering, communication system simulation and industrial statistical data analysis and other aspects. Its main characteristics are: (1) simple grammar, efficient, easy to operate; (2) Easy to learn and use because no special compiler is required; (3) Strong extensibility, allowing users to write library functions according to requirements; (4) Strong interaction and portability; (5) Strong computing power and system modeling and simulation ability.

2.2. “Phantom Traffic Jam”
With the expansion of urban roads, the urban transportation system is becoming more and more perfect, but traffic congestion is still a headache [10]. Especially on roads that are not completely saturated, when the otherwise smooth traffic suddenly becomes congested, and the first car in the queue does not have any accident. After a while, the congestion eased, and traffic flowed smoothly again. This phenomenon without warning is known as “phantom traffic jam”. In fact, on crowded roads, sudden braking or sudden lane changes by a driver can have a serious impact on the vehicles following them. Maybe the first car stayed for only a second, but the last car had to wait several minutes before starting again [11][12].

3. Principal Component Analysis
Firstly, the various factors that affect urban road traffic are analyzed. At present, there are many kinds of indexes to evaluate the traffic safety of urban road vehicles. Therefore, this paper adopts the method of linear analysis of main components to analyze them.

Standardizing raw data:

\[ X = \frac{(x - \mu)}{\sigma^2} \]

is used to standardize the five parameters of traffic capacity, traffic density, road coverage, vehicle volume and vehicle running speed, where \( \mu \) is the sample mean and \( \sigma^2 \) is the sample variance.

The correlation coefficient matrix \( R = (r_{ij})_{n \times n} \) is established:

\[
r_{ij} = \frac{\sum_{k=1}^{n}(x_{ik} - \bar{x})(x_{jk} - \bar{x})}{\sqrt{\sum_{k=1}^{n}(x_{ik} - \bar{x})^2} \cdot \sqrt{\sum_{k=1}^{n}(x_{jk} - \bar{x})^2}}
\]

Calculating the characteristic root \( \lambda_1 \geq \lambda_2 \geq \lambda_3 \cdots \lambda_p \geq 0 \) and unit eigenvector of \( R \):
The principal component $F_i = a_{i1}x_1 + a_{i2}x_2 + \ldots + a_{ip}x_p, i = 1, 2, \ldots, p$ and calculate the contribution rate and cumulative contribution rate of the principal component.

The contribution rate is:

$$\frac{\lambda_i}{\sum_{k=1}^{p} \lambda_k} (i = 1, 2, \ldots, p)$$

The results of equation are shown in Table 1.

**Table 1.** Principal component contribution rate

| Principal Component | Characteristic Value | Characteristic Value | Variance Contribution Rate |
|---------------------|----------------------|----------------------|-----------------------------|
| 1                   | 4.4625               | 88.6214              | 88.6214                     |
| 2                   | 0.33874              | 5.8741               | 95.1211                     |
| 3                   | 0.15321              | 4.1215               | 98.6741                     |
| 4                   | 0.06438              | 1.1472               | 99.7412                     |
| 5                   | 0.0057               | 0.2358               | 100.0000                    |

It can be seen from Table 1 that the cumulative contribution rate of the first three influencing factors has reached 98.617%, indicating that the first three parameters contain the information of all indicators.

**4. Simulation and Results**

**4.1. Simulation Results and Analysis**

(1) The first simulation

In this simulation, the traffic congestion and smooth condition are divided. In the sample classification analysis experiment, 500 groups of traffic data were randomly selected from 800 groups of normal traffic flow data and added to the non-traffic congestion sample database. On the other hand, 500 groups of data were selected from 800 groups of congestion samples and added to the congestion sample database. Then, two sets of data were randomly selected from each sample database as data sets for basic training and performance testing. In the process of selecting data, many invalid data are removed, to improve the quality of data in simulation. The simulation results are shown in Figure 1.
Figure 1. The statistical distribution of sample data in the first classification

As can be seen from Figure 1, the detection rate of non-congestion is 96%, the detection rate of congestion is 94.2%, and the error rate is 1.3%. The average detection time is 12s. This means that the detection system in this paper has high detection accuracy and short time.

(2) The second simulation

In this simulation, the congestion situation is divided into general congestion and serious congestion in detail. After the above classification, the classified samples were rearranged, and these samples were used as data test samples in the second classification experiment. Because the data of the first classification sample is limited, in the second classification, the training set sample is randomly selected from the total database again and added to the training and test set randomly. In the simulation process, different levels of congestion data were selected and processed. The simulation results are shown in Figure 2.

Figure 2. Statistical distribution of sample data in the second classification

Figure 2 shows that the detection accuracy of general traffic congestion is 95.8%, that of serious traffic congestion is 96.4%, and the average detection time of traffic congestion is 8s.
4.2. Selection of Traffic Flow Parameters
The state of the roads in urban roads can be divided into two types: non-congestion and congestion. For the non-congested traffic state, the traffic flow is relatively stable, and the change process is relatively gentle. When urban road congestion occurs, vehicle flow will be significantly reduced, vehicle speed will be significantly reduced, and the road occupancy rate will be significantly increased. Therefore, according to the significant characteristics of traffic congestion, this paper selects three parameters to evaluate traffic flow: volume, speed, and rate of flow.

4.3. Intersection Traffic Simulation Module
This module contains vehicles and lights. The left area of the module is the function menu, and the right area provides the function of display. The MATLAB command line is at the bottom. After clicking the save button in the function menu, the system will automatically close the interactive window and save the current data, and then return to the main simulation interface. The text box of this module can not only display MATLAB commands according to the parameters set by users, but also be used for user learning and testing. When you enter the command, the results will appear in the correct area.

5. Conclusions
In this paper, the “phantom traffic jam” phenomenon research based on MATLAB, the cause of the “phantom traffic jam” phenomenon has been deeply studied. According to the analysis, the seemingly mysterious phenomenon of “phantom traffic jam” is a chain reaction caused by special traffic jams. The phenomenon occurs without warning and so quickly that it is mistaken for a ghost. The traffic congestion model proposed in this paper gives a scientific explanation for this phenomenon and revives the phenomenon of “phantom traffic jam”. Then the accuracy of the prediction model is evaluated by simulation. On the other hand, the traffic congestion model can be used to analyze various possible traffic congestion phenomena and provide a data basis for road optimization in the form of simulation.

References
[1] H. Nadrian, M.H. Taghdisi, K. Poyyesh, M. Khazaee-Pool, T. Babazadeh, "I am sick and tired of this congestion": Perceptions of Sanandaj inhabitants on the family mental health impacts of urban traffic jam, Journal of Transport & Health, 14 (2019).
[2] N. Malvin, S.R. Pudjawarsetya, Staggered Conservative Scheme for Simulating the Emergence of a Jamiton in a Phantom Traffic Jam, International Journal of Intelligent Transportation Systems Research, (2020).
[3] R.E. Stern, S.M. Cui, M.L. Delle Monache, R. Bhadani, M. Bunting, M. Churchill, N. Hamilton, R. Hauley, H. Pohlmann, F.Y. Wu, B. Piccoli, B. Seibold, J. Sprinkle, D.B. Work, Dissipation of stop-and-go waves via control of autonomous vehicles: Field experiments, Transp. Res. Pt. C-Emerg. Technol., 89 (2018) 205-221.
[4] K. Goldmann, G. Sieg, Economic implications of phantom traffic jams: evidence from traffic experiments, Transportation Letters-the International Journal of Transportation Research, 12 (2020) 386-390.
[5] K. Fadhloun, H. Rakha, A. Loulizi, Macroscopic analysis of moving bottlenecks, Transportation Letters–the International Journal of Transportation Research, 11 (2019) 516-526.
[6] J.L. Luo, Y.S. Huang, Y.S. Weng, Design of Variable Traffic Light Control Systems for Preventing Two-Way Grid Network Traffic Jams Using Timed Petri Nets, IEEE Trans. Intell. Transp. Syst., 21 (2020) 3117-3127.
[7] G. Cavone, M. Dotoli, C. Seatzu, A Survey on Petri Net Models for Freight Logistics and Transportation Systems, IEEE Trans. Intell. Transp. Syst., 19 (2018) 1795-1813.
[8] M. Saberi, H. Hamedmoghadam, M. Ashfaq, S.A. Hosseini, Z.Y. Gu, S. Shafiei, D.J. Nair, V. Dixit, L. Gardner, S.T. Waller, M.C. Gonzalez, A simple contagion process describes
spreading of traffic jams in urban networks, Nat. Commun., 11 (2020) 9.

[9] H. Tampubolon, C.-L. Yang, A.S. Chan, H. Sutrisno, K.-L. Hua, Optimized CapsNet for Traffic Jam Speed Prediction Using Mobile Sensor Data under Urban Swarming Transportation, Sensors, 19 (2019).

[10] A. Paradise, C.B. Rocha, P. Barpanda, N. Nakamura, Blocking Statistics in a Varying Climate: Lessons from a "Traffic Jam" Model with Pseudostochastic Forcing, J. Atmos. Sci., 76 (2019) 3013-3027.

[11] S. Izhakian, Z. Itzhakov, O. Gorelik, Traffic jam and collateral pathways, Netherlands Journal of Medicine, 77 (2019) 268-269.

[12] C. Brennand, G.P. Rocha, G. Maia, F. Cunha, D.L. Guidoni, L.A. Villas, Towards a Fog-Enabled Intelligent Transportation System to Reduce Traffic Jam, Sensors, 19 (2019) 29.