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Analysis on route regulation of urban and rural traffic track based on GIS technology

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Abstract

The existing methods for regulating urban and rural traffic track routes have problems of poor vehicle operating order, long delays, poor control effects, low safety and long regulation time. An route regulation method for urban and rural traffic track based on GIS technology is proposed. Firstly, urban and rural traffic tracks are discretized to adjust the flow of urban and rural traffic tracks and eliminate vehicle conflicts; secondly, the characteristics of typical routing algorithms of METALINE and ALINEA for urban and rural traffic track are explained; Finally, on the basis of calculating the traction and running resistance of vehicles, the traffic flow discrete model of the traffic track route is constructed to complete the route regulation of urban and rural traffic track. The experimental results show that the proposed method has better vehicle operating order, lower long delay rate, higher safety and higher passenger satisfaction.

Key words - GIS, urban and rural traffic track, route regulation, ALINEA, METALINE, discrete model of traffic flow

1. Introduction

Under the background of economic globalization, the advancement of science and technology has made the transportation system into people's lives. The transportation system provides data support and technical support for the implementation and management of traffic safety measures [4], and people's demand for transportation also increases. The impact of this demand on the transportation system is not only reflected in the change in the number of trips, but also in the quality of travel services. Based on this, people have the new understanding of the transportation system. As an integral part of the entire social system [3], from the perspective of managers, the transportation system is more reflected in its social benefits and fairness. Urban and rural traffic track regulation is an important means to solve urban and rural traffic congestion, reduce urban and rural traffic accidents, and improve people's travel quality [8]. Combining the actual situation of urban and rural traffic track in China, the traffic signal coordination control problem of urban and rural roads is combined with the basic control theory of system engineering to analyze the importance of route regulation and improve the efficiency and safety of traffic in urban and rural traffic track [1].

With the advent of the information age, the current methods of orbital regulation have been unable to meet people's needs. How to realize the regulation of urban and rural traffic track in the information age has become the hot research topic for experts. For example, Wang et al. [12] propose the method for regulating urban and rural traffic track based on the traction electric drive

system of rail transit vehicles in the literature. The method firstly needs to analyze the characteristics of the traction electric drive system of the rail vehicle and propose the multi-mode modulation method. Then the characteristics of the multi-mode modulation method are analyzed. Finally, on the basis of the improved vector control method, the hybrid control method consisting of vector control and slip frequency control is proposed to regulate the urban and rural traffic track routes. However, this method has the problem that the vehicle is in the poor operating order. Another route regulation method for the traffic track based on the tourist attractions of Ganzi Prefecture is proposed in the literature [15]. It uses the Floyd algorithm to find the shortest path and distance between two points to regulate the urban and rural traffic track. However, this method is too simple to achieve the desired effect. Lu et al. [5] proposed a method for regulating the traffic orbit route based on network topology and passenger flow demand in literature. The method constructs the traffic track line regulation model with the maximum passenger flow turnover as the target, which regulates the urban and rural traffic track route by solving the regulation model of urban and rural traffic track line. The vehicle has good order of operation, but there is the problem of the long delay rate. Li et al. [6] in the literature propose a method of urban rail transit line regulation. The method divides the traffic line hierarchy according to the functional level line screening standard, and filters out the traffic track line to be adjusted. It regulates urban and rural traffic orbit routes by combining traffic classification and adjustment forms. The data to be processed by this method is highly complex, resulting in longer regulation time. Yan et al. [7] propose a method for regulating the traffic orbit route of fast road and multi-channel in the literature. The method firstly establishes a regulation model consisting of multiple ramps and traffic main lines according to the STNS model to analyze the influence of different signal control methods on traffic and complete the regulation of urban and rural traffic track routes. The method has low vehicle safety and is highly prone to traffic safety accidents.

The existing methods for urban and rural traffic track regulation have certain advantages to a certain extent, but ignore the influence of the vehicle's own vehicle traction and running resistance on the urban and rural traffic track regulation. This paper mainly considers this factor and can achieve effective regulation of urban and rural traffic track routes. So, the existing methods for regulating urban and rural traffic track routes have problems of poor vehicle operating order, long delays, poor control effects, low safety and long regulation time. The GIS-based urban-rural traffic track route regulation method is proposed. It greatly promotes the benign operation of the transportation system, ensures the safety of driving and people's property, and reduces the time required for urban and rural traffic track regulation.

2. Materials and methods

2.1. Control significance of the entrance ramp

Taking the urban and rural traffic track in Figure 1 as the research object, the research object is discretely processed by the time interval T . Assume that $d_i(k)$ (veh/h) is the traffic from the i -th entrance to the urban-rural traffic orbit by the time interval $[(k - 1)T, kT]$, and $s_i(k)$ (veh/h) is the traffic that leaves the urban-rural traffic track from the i -th exit by the time interval $[(k - 1)T, kT]$ [9].

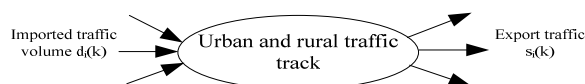


Fig. 1 - Abstract urban and rural traffic track route

Assume that $d(k) = \sum_{i=1 \sim n_1} d_i(k)$ and $s(k) = \sum_{i=1 \sim n_2} s_i(k)$ represent the total flow demand for the entrance and exit of the route [10], respectively, n_1 and n_2 represent the number of branches of the main road that are imported and exited. It is known that $d(k) = \sum_{i=1 \sim n_1} d_i(k)$ and its spatiotemporal distribution are not related to control measures; KT is the study time, and $T_S(K)$ is the total travel time of the traffic. The total travel time of the traffic flow is calculated as follows:

$$T_S(K) = T \sum_{k=1}^K N(k) \tag{1}$$

where, at KT , the formula for calculating the total number $N(k)$ of vehicles in urban and rural traffic tracks is as follows:

$$N(k) = N(k - 1) + T[d(k - 1) - s(k - 1)] = N(0) + T \sum_{\kappa=0}^{k-1} [d(\kappa) - s(\kappa)] \tag{2}$$

Substituting equation (2) into equation (1):

$$T_S(k) = T \sum_{k=1}^K [N(0) + T \sum_{K=0}^k [d(\kappa) - s(\kappa)]] \tag{3}$$

where, the first two items are not related to control measures. Let $T_S(K)$ be the smallest, namely:

$$\min S = -T^2 \sum_{k=1}^K \sum_{\kappa=0}^k s(K) = -T^2 \sum_{k=0}^{K-1} s(k) \tag{4}$$

where, κ represents the constant coefficient in the traffic flow. It can be seen from equation (4) that the earlier the vehicle leaves the urban and rural traffic track is, the shorter the total travel time is.

Assume that q_m is the flow of the upstream urban and rural traffic track route, d is the total inlet flow of the urban and rural traffic track route, and q_{con} is the main line capacity during the vehicle blockage time. Usually q_{con} is 90% to 95% of q_{cap} . If the total flow control of the urban and rural traffic track routes can ensure that the main line flow of the high-speed main road is q_{cap} nearby, there will be queuing on the branch road that merges into the main road. However, since q_{con} is smaller than q_{cap} , controlling the branch that flows into the main path can reduce the total travel time. The reduced travel time is calculated as follows:

$$\Delta T_S(K) = \frac{q_{cap} - q_{con}}{q_{in} + d - q_{con}} \tag{5}$$

In general, the effects of controlling the branch include the following:

- (1) Eliminate congestion and reduce travel time of vehicles;
- (2) Adjusting the incoming traffic of urban and rural traffic track routes, eliminating vehicle

conflicts and improving traffic safety;

(3) Improve the stability of traffic flow and reduce the discomfort of vehicle operation.

The above is the significance of the entrance ramp control for the regulation of typical urban and rural traffic track routes.

2.2. ALINEA and METALINE algorithms

The ALINEA algorithm is a control strategy for feedback control line branches [14]. The branch adjustments determined by the algorithm are as follows:

$$r(k) = r(k-1) + k_r(\hat{O}) - o_{out}(k-1) \quad (6)$$

where, $r(k)$ represents the branch regulation rate in the time interval $[(k-1)T, kT]$; k_r represents the amplification factor, which has a great influence on $r(k)$; \hat{O} is the expected occupancy rate of the downstream urban and rural traffic track, which is usually less than or equal to the critical occupancy rate; $O(k)$ is the actual occupancy of the urban and rural traffic track in $[(k-1)T, kT]$.

Considering the multi-section of urban and rural traffic tracks and the influence of multi-inlet branch regulation on traffic, the METALINE algorithm is proposed with the goal of maintaining multiple branches at the same time. The adjustment amount of each track branch is as follows:

$$r(k) = r(k-1) - K_1(o(k) - o(k-1)) + K_2(\hat{O} - O(k)) \quad (7)$$

where, $r(k) = [r_1(k), r_2(k), \dots, r_m(k)]$ is the vector consisting of m controlled entry adjustments in $[(k-1)T, kT]$, $o = [o_1, o_2, \dots, o_n]$ is the vector formed by the occupancy values measured by n urban and rural traffic track routes, $O = [O_1, O_2, \dots, O_m]$ represents the subset of the vector, which is the vector of the actual occupancy of the m controlled branches. The $\hat{O} = [\hat{O}_1, \hat{O}_2, \dots, \hat{O}_m]$ corresponds to O vectors, which is a vector consisting of the expected occupancy of the m controlled entry branches, $K_1 \in R^{m \times n}$ and $K_2 \in R^{m \times m}$ are the gain matrix of the regulator.

It can be seen from equation (7) that the effect of the METALINE algorithm depends on the accuracy of K_1 , K_2 and \hat{O} . The METALINE algorithm achieves better results than the ALINEA algorithm, but the process is relatively complicated and requires $m \times (m + n + 1)$ parameters to be set. Therefore, they have their own advantages in the regulation of urban and rural traffic routes.

2.3. Calculation of vehicle traction and resistance

The vehicle traction force is caused by the vehicle power transmission device, which is consistent with the driving direction and is an external force that can be adjusted. Since the vehicle is mainly exposed to air and orbit during operation, if the moving wheel of the vehicle is not in contact with the track, the mechanical energy transmitted to the moving wheel can only make the moving wheel rotate and cannot generate traction that leads the vehicle movement [13].

From the above, it can be known that the generation of traction force needs to satisfy the following conditions:

(1) The mechanical energy provided by the power transmission device is on the moving wheel of the vehicle;

(2) The moving wheel is in contact with the track and there is friction.

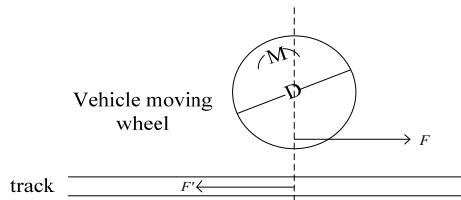


Fig. 2 -Traction generation diagram

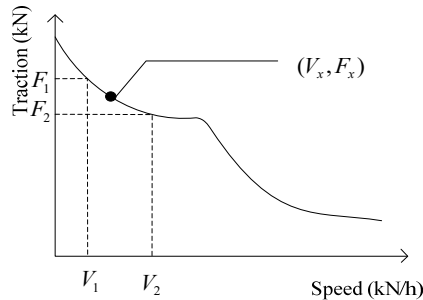


Fig. 3 - Linear interpolation method of traction characteristic curve

The mechanical energy transmitted to the moving wheel gives it a rotational torque. Under the action of the rotational moment, a relative motion is exhibited between the moving wheel and the track. If there is adhesion between the wheel and rail at this time, the moving wheel will exert a force on the rail, and at the same time the rail will generate a reaction force to the moving wheel, as shown in Figure 2, where D is the diameter of the moving wheel, and F and F' represent the force and reaction force. The force is calculated as shown in equation (8).

$$F = \frac{M}{D/2} \text{ (N)} \quad (8)$$

The vehicle traction is the sum of the reaction forces of all the moving wheels of the vehicle. The simple calculation is usually determined by the vehicle traction characteristic curve. Correspondence between speed and traction is obtained by linear interpolation or curve fitting, as shown in Figure 3, where (V_1, F_1) and (V_2, F_2) are two known points in the traction characteristic curve, and (V_x, F_x) is the speed between two points. Assume that V_x is the known point of traction waiting. The traction force F of V_x point is as follows:

$$F_x = F_1 + \frac{(V_x - V_1)(F_2 - F_1)}{V_2 - V_1} \quad (9)$$

The running resistance of the vehicle is an obstacle imposed on the vehicle by the external environment and is an external force that cannot be adjusted. Depending on the cause of the running resistance, the resistance is usually divided into basic resistance and additional resistance. The basic resistance is the resistance of the vehicle during operation. This resistance is derived from the frictional resistance of the vehicle, the sliding friction between the wheel and the track, air resistance, etc. [2]. The formula for calculating the basic resistance is as follows:

$$w_0 = a + bv + cv^2(N / kN) \tag{10}$$

where, v is the running speed of the vehicle. If v is less than 10, take $v = 10$. a , b and c represent the constant coefficients determined by the vehicle properties.

The additional resistance is not related to the vehicle running speed and vehicle properties. After entering the tunnel, the vehicle will accelerate the flow of air. Because the space of the tunnel is narrow, the friction between the air and the vehicle surface is intensified.

When the vehicle moves on the curved track, part of the wheel rim of the vehicle generates sliding friction with the track, and the wheel produces side slip, which causes the vehicle's motion resistance to become large. Since $w_{r'}$ has many influencing factors, the empirical formula is usually used to estimate the additional resistance:

$$w_{r'} = \frac{A}{R}(N / kN) \tag{11}$$

where, R represents the radius of the curve and A represents the constant determined by the experimental test.

According to the above content, the traction and running resistance of urban and rural traffic rail vehicles are calculated.

2.4. Construction of discrete model of traffic flow

In practical applications, the continuous model of traffic flow is usually processed discretely, and the Payne model is used to regulate the traffic flow of urban and rural traffic track routes [11]. Payne divides urban and rural traffic tracks into several sides based on the entrance branch and road width. Each side contains at most one entrance and exit, and their width does not change. Each side is divided into several segments, as shown in Figure 4.

The segments of the urban and rural traffic track shown in Figure 4 are numbered from left to right according to natural numbers. Suppose the control step size is N_c and the prediction step size is N_p . $q_j(k)$, $\rho_j(k)$ and $v_j(k)$ are the traffic volume, vehicle density and vehicle speed of each lane in section j at $[(k - 1)T, kT]$, respectively. $Q_j(k)$ is the traffic on the urban and rural traffic track lines. λ_j and L_j are the number and length of lanes in the j segment, κ and a_j represent the constant coefficients of the traffic flow model, $v_{free,j}$ is the free flow velocity of the main segment, $\rho_{crit,j}$ is the critical density of the main line segment, $w_j(k)$, $d_j(k)$, $r_j(k)$ and $s_j(k)$ respectively represent the queue length, demand, adjustment, and exit flow of the inlet branch connected to the main line segment j in $[(k - 1)T, kT]$. The macroscopic traffic flow discrete model of urban and rural traffic tracks can be expressed in the following form:

The basic model of traffic flow is

$$q_j(k) = \rho_j(k)v_j(k)\lambda_j \tag{12}$$

Discretizing the continuity equation, the resulting flow conservation equation is as follows:

$$\rho_j(k + 1) = \rho_j(k) + \frac{T}{L_j}(q_{j-1}(k) - q_j(k) + r_j(k) - s_j(k)) \tag{13}$$

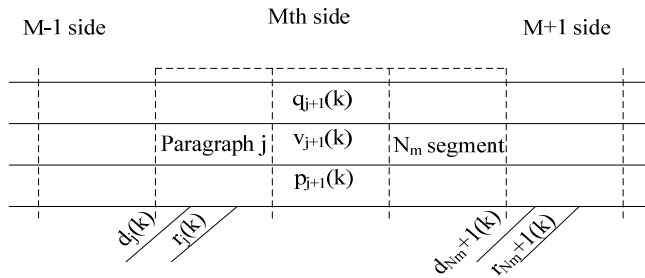


Fig. 4 - Division of urban and rural traffic track routes

Discretizing the Payne model, the resulting momentum equation is:

$$v_j(k + 1) = v_j(k) + \frac{T}{\tau} (V(\rho_j(k)) - v_j(k)) + \frac{T}{\tau_j} v_j(k)(v_{j-1}(k) - v_j(k)) - \frac{\eta T}{\tau L_j} \frac{\rho_{j+1}(k) - \rho_j(k)}{\rho_j(k) + \kappa} \quad (14)$$

where, The first item on the right is the average speed, the second item is the slack item, the third item is the convection item, and the fourth item is the expected item.

The equilibrium speed calculation formula is as follows:

$$V(\rho_j(k)) = v_{free,j} \exp \left[-\frac{1}{a_j} \left(\frac{\rho_j(k)}{\rho_{crit,j}} \right)^{a_j} \right] \quad (15)$$

The urban and rural traffic track route entrance branch traffic flow model consists of two parts: the queuing model and the adjustment amount constraint. The formula for calculating the queue length of the entrance branch is:

$$w_j(k + 1) = w_j(k) + T(d_j(k) - r_j(k)) \quad (16)$$

If $Q_{j,max}$ is the capacity of the urban branch rail route entrance branch j , $\rho_{j,max}$ is the maximum density of the main line segment j , then the adjustment amount constraint calculation formula is as follows:

$$0 < r_j(k) \leq \min \left[d_j(k) + \frac{w_j(k)}{T}, Q_{j,max} \frac{\rho_{j,max} - \rho_j(k)}{\rho_{j,max} - \rho_{crit,j}} \right] \quad (17)$$

where, the second item on the right is the change of the branch road caused by the limited crowding of urban and rural traffic tracks.

So far, the traffic flow discrete model of urban and rural traffic track routes has been constructed to achieve the regulation of urban and rural traffic track routes.

3. Results

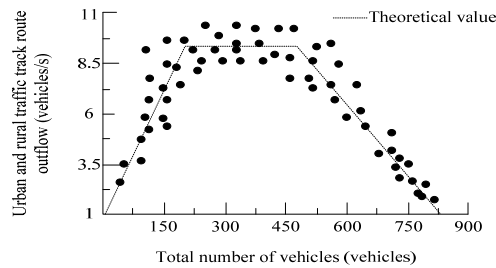
In order to verify the superiority and effectiveness of the proposed method, MFD curves and vehicle safety are performed with the literature method [5-9]. The macroscopic basic map of the road network is the restoration of the actual road conditions from the acquired vehicles and road

data before the regulation. The urban and rural traffic track routes of a certain city in a certain city were randomly selected as experimental subjects, and the experiment time was 1 year. In the Windows 10 system environment, the control effects of the proposed method and the five literature methods were compared and analyzed.

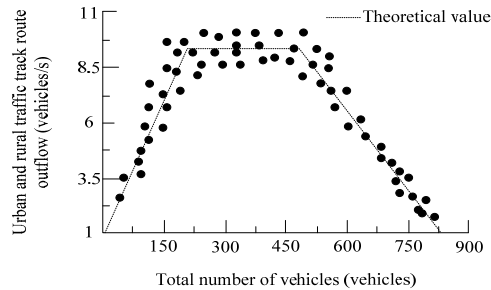
In the comparison of MFD curves, the fitting degree of the method curve with the theoretical value is very high, which indicates that the method has high degree of reduction on the outflow of urban and rural traffic track routes, which is close to the actual situation. In the safety comparison test, the less the number of safety accidents occurred within a certain period of time, the higher the safety of the control method. The specific experimental results are as follows:

(1) Comparison of MFD curves

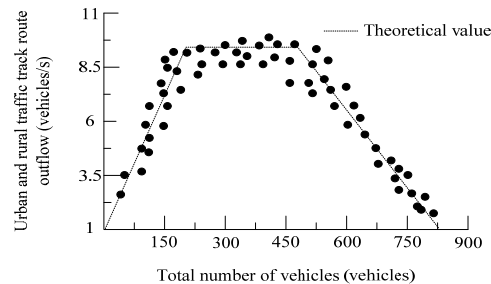
The comparison results of the MFD curves of the proposed method [5-9] are shown in Figure 5. The abscissa is the total number of vehicles; the ordinate is the outflow of urban and rural traffic track routes.



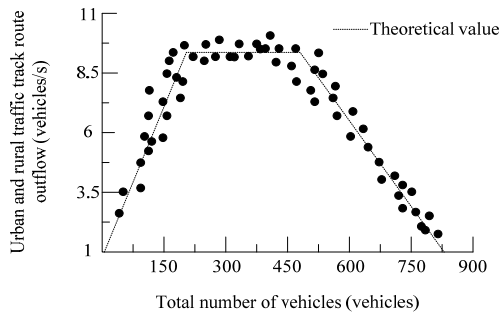
(a) MFD curve of the method [5]



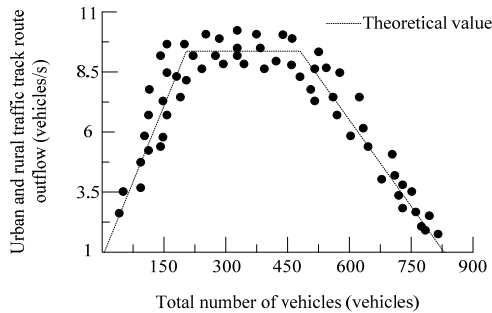
(b) MFD curve of the method [6]



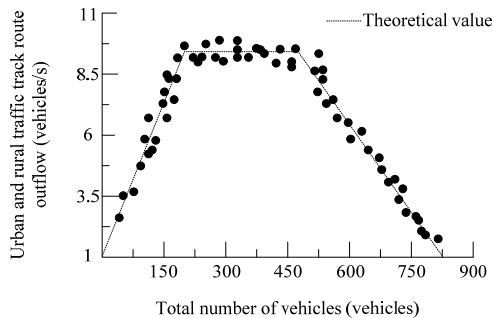
(c) MFD curve of the method [7]



(d) MFD curve of the method [8]



(e) MFD curve of the method [9]



(f) MFD curve of the proposed method

Fig. 5 - Comparison of MFD curves

It can be seen from Figure 5 that among the six orbital route regulation methods, the proposed control method has the best regulation effect, and the MFD curve is closest to the theoretical value. This is because the proposed method uses GIS technology, which greatly promotes the benign operation of the transportation system. The proposed regulation method can make the vehicles running on the urban and rural traffic track routes more orderly and reduce the occurrence of accidents.

(2) Comparison of safety of several control methods

The number of safety accidents after the regulation using the proposed method [5-9] are respectively compared with the situation before regulation, and the results are shown in Table 1.

Tab. 1- safety comparison

Regulation method	Number of security incidents before regulation (times)	Number of security incidents after regulation (times)
Proposed Method	6	1
Literature [5] method	6	3
Literature [6] method	6	5
Literature [7] method	6	4
Literature [8] method	6	3
Literature [9] method	6	4

As can be seen from Table 1, the subject had six safety incidents within one year. After six methods were adopted, the occurrence of safety accidents is controlled, and the proposed method had the best control effect, which was 83% lower than the number of accidents in the previous year. It can be seen that the proposed method can make the vehicles running on the urban and rural traffic track routes safer.

4. Discussion

Aiming at the existing control methods of urban and rural traffic track routes, there are problems of poor vehicle operation order and poor safety. The method for regulating urban and rural traffic track routes based on GIS technology is proposed. The experimental results show that compared with other methods, the proposed method has better order and higher safety.

In order to verify the effectiveness of the traffic flow discrete model and algorithm for urban and rural traffic track routes, the network in Figure 6 is used as an experimental background.

Assume that the vehicle's waiting node has a safe capacity of 50 people, the vehicle is arbitrarily limited to 40 people, the vehicle capacity constraint is 125% of the vehicle-limited personnel, the vehicle's departure interval is 15 minutes, and the station's stop time is 25 seconds. The running time is 3 minutes. The vehicle's long delay time reference is 6 minutes and the reference number is 50. Assume that all passengers have a destination of C, and the time-shared passenger traffic of each vehicle site is the same. The time-sharing demand is shown in Table 2.

Simulation experiments are performed on the computer with Intel Core i5, 2.50 GHz CPU and 8 GB RAM.

The proposed method [5-9] are named A1, B2, C3, D4, E5, and F6, respectively. The unit of delay time is seconds, and each method runs 25 times. It can be seen from Table 3 that the indicators of the proposed method are better than the literature methods.

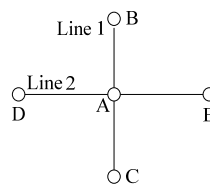


Fig. 6 - Network background

Tab. 2 - Time-sharing demand

time	6.30~7.00	7.00~7.30	7.30~8.00	8.00~8.30	8.30~9.00
people	15	20	30	20	15

Tab. 3 - Comparison of solutions for different control methods

Control method name	Number of runs (times)	The optimal value		Average value	
		ATD	MTD	ATD	MTD
A1	25	153	532	156	579
B2	25	191	810	216	1030
C3	25	183	645	181	680
D4	25	157	560	163	587
E5	25	165	583	172	613
F6	25	172	596	179	620

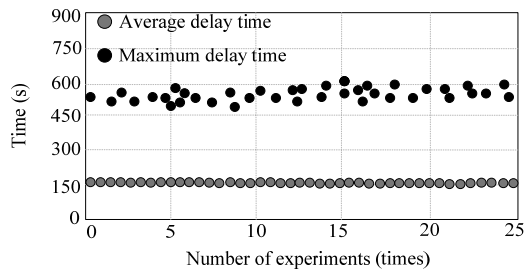


Fig. 7 - Optimal result distribution map

Tab. 4 - Comparison of the maximum number of passengers delayed at each station

Whether to carry out limited regulation	Delay type	Number of delays at Site A (person)	Number of delays at Site B (person)	Number of delays at Site C (person)	Number of delays at Site D (person)
y	Delay outside the station	7	13	15	12
	Delay in the station	16	0	0	0
n	Delay outside the station	0	0	0	0
	Delay in the station	62	0	0	0

It can be seen from Table 3, where, ATD is delay time and MTD is maximum delay time, that the distribution of the average delay time and the maximum delay time of the proposed method after 25 runs is shown in Figure 7.

The comparison of the maximum number of delays in the case of regulation and non-regulation is shown in Table 4. In Table 4, the number of station delays under regulation indicates the maximum number of transient delays generated by each station during the entire regulation period. When the same passenger is delayed at two stations, it will be counted in the statistics of the delays of the two stations. After the inbound passenger flow is regulated, the number of passengers at the A station is reduced because the incoming passenger flow of other vehicle parking stations is controlled outside the station.

Passenger flow control reduces the number of passengers with longer delays, which increases the number of passengers with shorter delays. This shows that the proposed control method can significantly reduce the occurrence of long delays in the station, and can effectively alleviate the long delay caused by the supply and demand matching.

In summary, the proposed method achieves the regulation of urban and rural traffic orbital routes on the basis of ensuring better operational order and higher safety. Moreover, it can significantly reduce the occurrence of long delays, and better alleviate the long delay of supply and demand matching.

5. Conclusions

With the continuous development of urban-rural integration, traffic accidents have occurred from time to time. How to ensure urban and rural traffic safety and improve people's travel quality has become one of the problems that need to be solved in modern traffic. The existing methods for regulating urban and rural traffic track routes have problems of poor vehicle operating order, long delays, poor control effects, low safety and long regulation time. The GIS-based urban-rural traffic track route regulation method is proposed. The effectiveness and superiority of the proposed method are verified by experiments, which can reduce the time required for urban and rural traffic track regulation, greatly promote the benign operation of the traffic system, ensure the safety of traffic and people's property, and realize the effective regulation of urban and rural traffic. New ideas have been provided for the regulation and development of urban and rural traffic rail routes.

However, the method of regulating urban and rural traffic orbits is not absolute, and there are loopholes in any method. In order to more accurately regulate the urban and rural traffic track routes, it is necessary to conduct continuous and in-depth research on urban and rural traffic track regulation methods. Looking to the future, we must carry forward the spirit of exploration and provide people with safer and higher quality travel services.

Acknowledgments

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Method for traffic safety state detection of urban road based on cloud architecture

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Abstract

Aiming at the problems of poor real-time performance and accuracy, high complexity and energy consumption in current traffic safety state detection, a method for traffic safety state detection of urban road based on cloud architecture is proposed. According to the overall structure of traffic safety state detection of urban road under cloud architecture, data mining processing of urban road traffic is realized through missing data repair and error data filtering. Based on the results of data processing, the road traffic system is divided into three parts: participants, objects and traffic organization and management. The representative indicators of the three parts are selected as indicators of traffic safety status detection. Rough set is introduced to determine the weight of detection indicator by constructing decision table, calculating attribute dependence degree, calculating the importance degree of an attribute and normalizing the calculation result of indicator importance degree. Combining the comprehensive score of the detection indicators and the comprehensive weight of the indicators, the detection model is constructed to realize the traffic safety state detection. The experimental results show that the method has high detection efficiency and accuracy, low complexity and energy consumption, as well as strong robustness.

Keywords - cloud architecture, road traffic, safety, detection

1. Introduction

Practical results show that traffic congestion and accidents are the main traffic safety problems faced by modern cities [1, 7]. With the continuous development of social economy, increasing vehicles and increasing traffic demand, traffic safety condition detection of urban road has become the focus of urban traffic research. The rapid increase of malignant traffic accidents and traffic congestion has seriously threatened people's safety of life and property, and seriously reduced the efficiency of traffic operation [5]. For the purpose of improving traffic safety and operation efficiency, experts and scholars in this field use advanced technology to detect traffic safety status, and many excellent research results have emerged.

Zhang et al. [11] put forward the method of traffic safety state detection on expressway in foggy weather. Based on the observation data of highway in foggy days, the obtained data were input into VISSIM simulation software to realize highway traffic condition detection in different environments. The correlation between visibility in foggy days and traffic flow parameters and traffic safety state was simulated and analyzed. The number of traffic conflicts was regarded as a description parameter of traffic safety state. The key indicators affecting traffic safety were

determined by random forest algorithm. At the same time, the calculation model of traffic conflict number in foggy days was constructed based on regression analysis method to complete traffic safety state detection. The experimental results showed that the method had strong pertinence, but it had the problem of poor real-time performance. Gao et al. [3] combined the number of accidents with casualties in traffic accidents, and combines the fusion results with the number of motor vehicles and the number of casualties in a certain area, so as to obtain the actual situation of traffic accidents and casualties, get the indicator of traffic safety degree, and complete the traffic safety state detection. The experimental results showed that the method was simple and theoretical, but the detection accuracy was poor. Ma et al. [6] proposed a comprehensive traffic safety detection method based on entropy weight theory. In order to enrich and improve the domestic traffic safety detection methods, the entropy weight theory and star graph analysis method were integrated into the comprehensive traffic safety detection. The detection method was based on the detection system constructed by quantitative indicators, and the construction process of comprehensive detection model was given. At the same time, the traffic safety information data of Shandong Province in recent five years were taken as example to realize the comprehensive detection practice. The experimental results showed that the process of this method was simple and the results obtained were very intuitive, but there was a problem of poor accuracy. Yang et al. [9] presented a method for traffic safety state detection of urban road based on neural network model. In order to improve the traffic situation, a traffic safety detection indicator system was constructed according to the overall operation of road traffic, and a neural network model for traffic safety detection and diagnosis was designed and constructed. In the process, the combined weight detection and evaluation model judged the subjective and objective weights of the detection indicators by AHP method and entropy weight method respectively. At the same time, the combined weights were fused to get the combined weights, so as to diagnose the traffic safety status. The evaluation model of neural network realized the memory learning of existing samples through the algorithm of artificial neural network, and calculated the indicator data to be evaluated, and then obtained the road safety grade. The experimental results showed that the method had high detection accuracy, but it had the problem of high complexity of detection process. You et al. [10] proposed a method for traffic safety state detection of urban road based on support vector machine model. The traffic condition before the actual accident was regarded as the judgment criterion of bad traffic condition. Traffic flow data were extracted, and the dimensionality of the data was reduced by the principal component analysis method to obtain nine main parameters. A support vector machine (SVM) model for traffic safety detection based on radial basis function (RBF) was constructed. The penalty parameters and kernel parameters of SVM were calculated according to the grid traversal method. The final support vector machine model was regarded as an important way of traffic safety detection. The experimental results showed that the recall rate of this method was ideal, but the detection energy consumption was high.

Current methods for traffic safety state detection do not specifically analyze the functions of traffic safety detection, and do not further process the traffic data obtained, which leads to the problems of poor real-time performance and accuracy, high complexity and energy consumption of existing methods. Therefore, the relevant methods for traffic safety state detection need to be improved, and the method for traffic safety state detection of urban road based on cloud architecture is proposed.

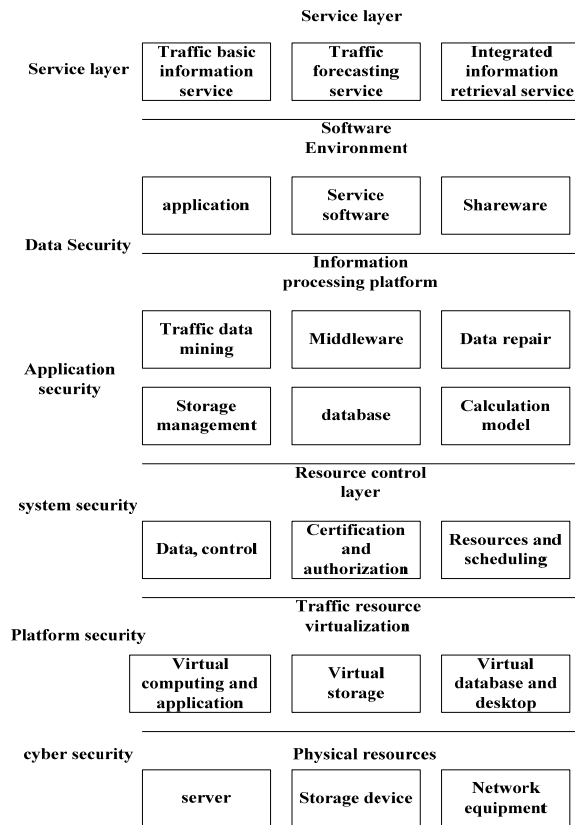


Fig. 1 -The overall framework of traffic safety condition detection of urban road based on cloud architecture

2. Method for traffic safety state detection of urban road

2.1. Analysis of detection logic architecture based on cloud architecture

According to the function analysis of traffic safety detection, the detection structure can be logically divided into physical resource layer, traffic data virtualization layer, data control layer, service layer, security layer and management layer, as shown in Figure 1.

Analysis of Figure 1:

(1) Physical data resource layer includes physical devices such as grid, computing and storage, which can be integrated into the equipment and facilities of traffic management information data center.

(2) Virtualization resource layer mainly uses cloud computing technology to abstract traffic data resources in physical layer, so that traffic resources can be allocated.

(3) The main task of traffic resource control layer is to manage virtual resources and provide services for service layer.

(4) Service layer is mainly based on SOA architecture. Traffic data processing cloud platform is mainly composed of various software in application layer and management of underlying resources, including traffic data mining and storage management. The framework can provide users

with traffic forecasting information services and comprehensive information retrieval services.

(5) The security layer is a layered defense system for the overall framework, which mainly includes user security and data security.

(6) Management is mainly to improve the overall utilization rate of traffic resources, manage the operation configuration of the whole structure and the operation of each level in the detection system. It mainly includes service management and resource management.

The above is the whole process of traffic safety state detection of urban road using cloud architecture. The traffic state detection and early warning based on virtual data management can effectively enhance the real-time performance of traffic state detection.

2.2. Traffic data processing

From 2.1, it can be seen that data mining is an important prerequisite for traffic safety state detection of urban road. Next, the traffic data of urban road are mined and processed in two aspects: missing data repair and error data filtering, which lays a foundation for traffic safety state detection.

To a certain extent, the main trend of traffic flow change has regularity and universality, and the real-time traffic flow of adjacent lanes at the same time can largely reflect the real traffic flow of the lane [12, 13]. The method of combining historical trend data with real-time data of adjacent lanes is proposed to repair missing data. The detailed process is as follows.

Step (1): analyze the law of historical traffic data and calculate the historical trend data by this law, as shown in Formula (1):

$$y^k(t) = \partial y(t) + (1 - \partial)y^{k-1}(t) \quad (1)$$

In formula (1), ∂ represents the weighting coefficient, which can reflect the role of current measured data in historical traffic data. $y^k(t)$ represents the historical trend data of the time t on the k th day and $y^{k-1}(t)$ represents the historical trend data of the time t on the $k - 1$ th day.

Step (2): according to the historical trend data $y^{k-1}(t)$ of time t on day $k - 1$ and the measured data $y_{nl}(t)$ and $y_{nr}(t)$ of two adjacent lanes at time t on day k , the traffic data needed to be repaired are obtained.

$$y_n(t) = \beta \frac{y_{nl}(t) + y_{nr}(t)}{2} + (1 - \beta)y_n^{k-1}(t) \quad (2)$$

In formula (2), β represents the weighting coefficient, $y_n(t)$ represents the measured data of the repaired n th lane, and $y_n^{k-1}(t)$ represents the historical trend data of the n th lane at T -hour on day $k - 1$.

By comparing the current excellent filtering methods, the exponential smoothing method is selected to filter traffic data. According to the actual situation of the detection system, the average difference is chosen as the basis of the smoothing method.

By eliminating the maximum and minimum of data, exponential smoothing method is used to obtain the smoothing value of the time series of the data, so as to distinguish the basic data from the random variable data and filter out the discrete data. Only the observation value of the current period and the smoothing value of the previous period are needed to complete the filtering process of the data. The above mathematical models can be expressed as follows:

$$S_t = S_{t-1} + \alpha(X_t - S_{t-1}) \quad (3)$$

In formula (3), α represents the weighting coefficient and $X_t - S_{t-1}$ represents the pre-error value.

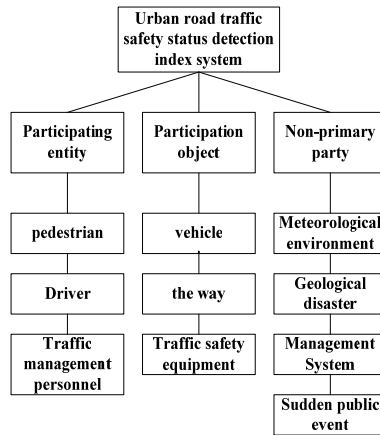


Fig. 2 - Indicator System of Traffic Safety State Detection

The above-mentioned missing data repair and error data filtering can effectively reduce the complexity of traffic safety state detection process, and thus reduce the detection energy consumption [8, 14].

2.3. Selection of detection indicator

Based on the overall structure of traffic safety state detection of urban road based on cloud architecture and traffic data processing, the road traffic system is divided into several parts: participants, objects and traffic organization and management. The main indicators are traffic status detection indicators. Figure 2 is the construction of traffic safety state detection indicators from the above three directions.

According to Figure 2, the detection indicators are calculated and analyzed.

(1) Indicators of traffic participants

(a) The proportion of drivers with driving age less than one year

Name of test indicator: percentage of driving age in one year

$$p = \frac{\text{Number of drivers with driving age in one year}}{\text{Total number of drivers}} \times 100\% \quad (4)$$

The characteristic of the indicator is dynamic, and the main source of the indicator is the database of traffic management research institute.

(b) Increase rate of drivers' key illegal accidents: this indicator is dynamic and timeliness, and the main source is the database of traffic management research institute.

(c) Traffic police allocation: there is an asymmetric Sigmoid function correlation between traffic police resource allocation and traffic accident rate.

$$AR(x) = \frac{\theta}{1 + e^{\lambda(x-d)}} + \eta \quad (5)$$

In formula (5), $AR(x)$ represents the accident rate, x represents the density of traffic police allocation, θ represents an adjustment parameter, η represents the accident rate caused by motor vehicle failure and driver's mistake, λ represents the role of traffic police in traffic safety, and d represents the parameter controlling the number of traffic police attendance.

(2) Indicator of traffic participation object

(a) Vehicle scrap rate: the number of vehicles that should be eliminated on schedule in a city accounts for the percentage of the total registered vehicles:

$$P' = \frac{\text{Number of vehicles responding to scrap}}{\text{Number of vehicles in possession}} \times 100\% \quad (6)$$

The indicator is dynamic and independent.

(b) Vehicle inspection rate: the number of vehicles participating in safety technology inspection on schedule in a city accounts for the percentage of registered vehicles in the city [4, 2]. Its expression is:

$$P'' = \frac{\text{Number of vehicles to be inspected}}{\text{Number of vehicles in possession}} \times 100\% \quad (7)$$

The indicator is also dynamic and independent.

(c) Unrenovated rate of dangerous sections: the number of unrenovated dangerous sections in a designated area of the city accounts for the percentage of all dangerous sections that have been detected:

$$P''' = \frac{\text{Number of actual unrenovated dangerous sections}}{\text{Total number of dangerous sections detected}} \times 100\% \quad (8)$$

The indicator has policy characteristics, and the main source is the local traffic management department database.

(3) Traffic environment and management indicators

The proportion of unfavorable days of rain, snow and fog: the proportion of unfavorable days of rain, snow and fog in a city's total detection cycle is:

$$P_1 = \frac{\text{Total number of three adverse weather events}}{\text{Total days of detection cycle}} \times 100\% \quad (9)$$

The indicator is predictable.

2.4. Construction of traffic safety state detection model

Based on the determination of detection indicators in Section 2.3, the weight of indicators is determined by rough set, and then the traffic safety state detection model is constructed.

Among them, the determination of indicator weight by rough set can be divided into the following steps:

(1) Construction of decision table. Rough set can only deal with discrete data. For quantitative indicators, the original data should be tempered and discretized. According to the qualitative indicators, each attribute indicator is evaluated with 1-3 scores by expert scoring. Each detection indicator is regarded as condition attribute $C = (c_1, \dots, c_n)$ in the decision table, and the result of traffic safety state detection of urban road is called decision attribute set D .

(2) To calculate the degree of dependence on attributes, the first step is to calculate the decision attribute D . The expression of the degree of dependence on the conditional attribute c_i is as follows:

$$r_c(D) = \frac{D}{U} \cdot y_n(t) \cdot S_t \quad (10)$$

According to the above calculation, after removing a certain attribute c_i , the dependence degree of decision attribute D . on conditional attribute set $C - c_i$ can be expressed as follows: