Research on intelligent transportation solution based on big data mode

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Abstract. This paper presents an intelligent traffic road resource allocation solution based on the traffic big data model. Through the collection and analysis of road traffic information big data, a planning scheme that can minimize road congestion when shared road resources between manned vehicles and unmanned vehicles is established. In order to alleviate the traffic congestion caused by the imbalance between road resources and traffic demand, taking 2020 as an example, the road congestion level is solved and given. When the judgment criterion is between 0 and 0.5, the road congestion level is set to level 3. When the judgment criterion is between 0.5 and 1, the road congestion level is set to level 2, and the remaining levels are level 1 and level 4. When: 1. The speed of the front car before braking is $v_s = 40 km/h$. 2. The speed of the rear car before braking is $v_s = 60 km/h$, and the car is moving at a constant speed in a short time. 3. When the dry asphalt pavement is taken $a_{s\text{max}} = 6m/s^2$. 4. When the wet asphalt pavement is $a_{s\text{max}} = 4.5 m/s^2$. The degree of road congestion is level 1.

1. Introduction
In the urban transportation field, traffic data such as network traffic data, public transportation data, urban vehicle GPS data, and video surveillance data provide solutions and decision support for urban intelligent transportation and mitigation. With the wide application of information technology, sensing technology and electronic technology in the automotive field, research based on traffic-related big data can find the causes of traffic congestion and the laws of people and motor vehicles, thus giving the best travel solution.

Driverless cars will gradually enter the road for some time to come. The occurrence of traffic congestion is inseparable from the unequal road resources and traffic demand. The rapid development of the economy leads to the imbalance of traffic demand and traffic supply, which is the root cause of serious traffic congestion. The mixed operation of two types of driving vehicles is an inevitable trend. The production of driverless cars is like a double-edged sword. Without reasonable traffic guidance and rules, it is bound to cause traffic uncertainty and congestion caused by traffic chaos [1-9]. For example, the transmission of brake waves caused by a red light can cause slow driving or even blockage [10-13]. Under normal driving conditions, in order to reduce the increasingly serious economic losses caused by traffic congestion, the United States introduces the National Strategy for Reducing Traffic Network Congestion in the United States, which analyzes the causes of traffic congestion. The strategy believes that today's traffic management measures cannot fully utilize the existing road settings, resulting in low traffic capacity, traffic congestion, frequent traffic accidents, traffic signal failures, abnormal weather conditions, large-scale activities, etc., which will cause traffic congestion. [14-21]. Traffic congestion on the road is usually caused by the following three conditions [22-27]. 1. Traffic congestion caused by random events:
random factors lead to a large number of traffic congestion, such as sudden traffic events, activities with a large number of traffic attractions, road construction and abnormal weather conditions. There are no signs of these incidents. If they are not evacuated and guided in time, regional traffic congestion is likely to occur. 2. Congestion caused by low traffic capacity of the road network: it is often caused by poor road design or road convergence. 3. Congestion caused by insignificant road signs: The lack of road guidance signs causes traffic to flow to the main trunks, resulting in excessive traffic on the main roads and slow travel speeds, resulting in congested queues [28-33].

When the driverless car enters the traffic road and shares the road with the driver's car in the initial, medium and perfect period, the road congestion status and principle they share are different [34-30]. In the early days when the unmanned vehicle enters the shared road, the previous transportation system is too small to provide sufficient transportation supply. Traffic congestion causes limited urban development. At the same time, road expansion is limited, public transportation capacity is limited, and unmanned vehicles could not be smoothly integrated into the road. Urban traffic congestion will have a chaotic and peak period of accidents. In the middle of the sharing, the driverless car and the manned motor vehicle driving on the road are in a balanced state. At this time, the traffic congestion state is a stable state that can be predicted. At the beginning of the sharing stabilization period, road congestion is inversely proportional to the vehicle. Road congestion will gradually decrease with the increase of the proportion of self-driving vehicles. When the proportion of self-driving vehicles reaches 80%, the congestion ratio decreases from 90.8% to 47.77%. Reduced by about half, greatly alleviating traffic congestion. This is because the response time of the self-driving vehicle system is relatively short, and the corresponding required safety distance is relatively small, so that the limited space can be utilized to achieve faster driving. However, in the middle and late stages of the sharing stable period, because the driver is liberated, while traveling and rest can be completed in the car at the same time, people may stay longer in the car and travel farther. At this time, traffic may increase congestion [31-40].

The state of road congestion is dynamic in a certain period. When the driverless car makes breakthroughs in technology and law, the number of driverless cars will be a kind of “spurt” growth. There will be a peak of road congestion. The economic, cultural, political, social activities of the city and the smooth flow of road traffic are often not positively related [41-58]. The rapid advancement of urbanization and the rapid development of social economy, the rapid increase in the number of urban residents lead to the emergence of traffic congestion.

Based on the traffic big data model, this paper gives the intelligent traffic road resource allocation solution. Through the collection and analysis of the road traffic information big data, the traffic resources and status information are fully perceived and controlled to realize data fusion, video resource sharing and auxiliary roads traffic command decision.

Taking a public resource of a certain Q city as an example, according to the traffic data to explore the path of manned and unmanned car sharing resources of road congestion characteristics, combining the dry or wet state of the road. Based on the setting of the number of manned and driverless cars, the degree of road congestion is classified and the planning scheme to minimize the degree of road congestion is given.

2. Optimal configuration plan
Consider the urban public infrastructure road resources, and make the following basic assumptions in combination with the actual road environment: 1. Assume that the number of urban residents is \( n > 1 \). For the public infrastructure of Q City, such as roads, all residents have the right to freely enjoy, and the maximum benefit each resident receives depends on whether to buy a car or how to use a car. 2. Assume that for every resident who owns a car, the satisfaction of the car is the same. And every resident knows the cost of owning or driving a car. At the same time, they know the total number of cars that can be carried on the roads in their Q city, that is, the car load capacity \( G \), in units of 10,000. These are all attributed to the static game theory of complete information. 3. Assume that the average benefit of the car (represented by \( V \)) is affected by the total number of cars owned by all residents of Q City, so \( V \) is
a function of \( G \), which is \( V = V(G) \). There is a maximum vehicle \( G_{\text{max}} \) in the roads of each city. Obviously, when \( G < G_{\text{max}} \), \( V(G) > 0 \), \( V(G) \) is the convex function of the monotonically decreasing function of \( G \). When \( G \geq G_{\text{max}} \), \( V(G) = 0 \). When there are few cars on the road, adding a few cars will not have much adverse effect on other cars. But as the number of cars continues to increase and is close to the largest car load on urban roads, the benefits of using each car to its owners will drop dramatically. Therefore, \( V'(G) < 0 \), \( V''(G) < 0 \).

It can be seen that the efficiency of the use of each car to its owner decreases as the number of cars purchased by urban resident’s increases. 1. There are \( n \) residents in \( Q \) city. 2. The number of cars owned by the \( i \)-th resident is \( g_i \in [0, \infty) \), and \( g_i \) is chosen to maximize its own benefits. 3. The price of the \( i \)-th resident purchasing a car is \( c \), then the total number of cars owned by all residents of the city is:

\[
G = \sum_{i=1}^{n} g_i
\]

(1)

The profit function is:

\[
\pi_i(g_1, g_2, \ldots, g_n) = g_iV\left(\sum_{j=1}^{n} g_j\right) - g_i c
\]

(2)

Using the principle of maximization, the first order of equation (2) is derived and set to zero. The first-order condition for optimization is:

\[
\frac{\partial \pi_i}{\partial g_i} = V(G) + g_iV'(G) - c = 0
\]

(3)

In the formula (3), \( V'(G)g < 0, V(G) > 0 \). Therefore, the addition of a car to a resident has two effects: on the one hand, the utility of the car itself, which is \( V \); on the other hand, the car has reduced the efficiency of use of all previous cars. The above-mentioned (4.3) type first-order conditions are combined to obtain the optimal number of cars \( g_i^* \) for each resident:

\[
g_i^* = g_i\left(g_1, \ldots, g_{i-1}, g_{i+1}, \ldots, g_n\right)
\]

(4)

Because of:

\[
\frac{\partial^2 \pi_i}{\partial g_i^2} = V'(G) + V''(G)g_i < 0 \text{ and } \frac{\partial^2 \pi_j}{\partial g_i \partial g_j} = V'(G) + V''(G)g_j < 0
\]

Then:

\[
\frac{\partial g_i}{\partial g_j} = -\frac{\partial^2 \pi_i}{\partial g_i \partial g_j} \cdot \frac{\partial^2 \pi_j}{\partial g_i^2} < 0
\]

(5)

(6)

The formula (6) indicates that the maximum number of cars for the \( i \)-th resident decreases as the number of cars of other residents increases. The \( n \) first-order conditions are combined and intersected at the Nash equilibrium point \( g^* = (g_1^*, \ldots, g_i^*, \ldots, g_n^*) \). The total number of cars in the Nash equilibrium point \( Q \) city is:

\[
G^* = \sum_{i=1}^{n} g_i^*
\]

(7)

Adding the first-order conditions that optimize the profit of \( n \) residents, it can be obtained:

\[
V(G^*) + \frac{G^*}{n} V'(G^*) = c
\]

(8)

The goal of society as a whole is to maximize the total social surplus:

\[
\max_{G} GV(G) - c
\]

(9)
The first-order condition for optimization is:
\[ V(G^*) + G^* V'(G^*) = c \]  
\[ (10) \]
Among them, \( G^* \) in formula (10) is the quantity of cars in Qingdao. Because \( [V(G) + GV'(G)] = 2V'(G) + GV^*(G) < 0 \), \( V(G) + GV'(G) \) is a subtraction function. Adding \((n-1)\frac{G^* V'(G^*)}{n}\) to both sides of equation (8), we can get:
\[ V(G^*) + G^* V'(G^*) = c + \frac{(n-1)G^* V'(G^*)}{n} < c = V(G^*) + G^* V'(G^*) \]  
\[ (11) \]
It can be seen that \( G^* < G^* \). Because residents regard urban roads as public resources, only considering their positive effects, and do not consider the overall benefits of society. The result is that the total car ownership of the Nash equilibrium is greater than the social optimal car ownership. In fact, the largest car load on urban roads is lower than the optimal car ownership in the society, which makes the use of road resources excessive, and ultimately leads to traffic congestion.

3. Road congestion degree classification and prediction

With the rapid development of artificial intelligence technology, the future traffic of Q City will inevitably have the integration of driverless cars. It is a long process from driverless cars being gradually put into the field of transportation and then into families to the withdrawal of driverless cars. Driverless cars and manned vehicles will share road resources for a period. In order to minimize road congestion, improve traffic efficiency, and alleviate traffic congestion, road resources are analyzed below.

Assume that in the future transportation network, there are \( x \) manned cars, \( y \) driverless cars, unit: 10,000. Let \( G = x + y \). Then the following target planning equations can be listed:
\[ \max \ Gv(G) - Gc \]
\[ \text{subject to } x \leq G^*, \quad \eta_1 \leq \frac{x}{x+y} \leq \eta_2, \quad 0 \leq y < \mu G^* \quad \text{and } x, y \text{ are integer} \]  
\[ (12.1) \]
In the equation (12.1), \( \eta_1, \eta_2 \) represents the proportion of the total number of unmanned vehicles driven by a manned motor vehicle; \( \mu \) represents the proportion of unmanned vehicles in car ownership. Since \( V(G) \) is the convex function of the monotonically decreasing function of \( G \), the equation (12.1) can be simplified as:
\[ \min \ G = \min \ x + y \]
\[ (12.2) \]
\[ \text{subject to } x \leq G^*, \quad \eta_1 \leq \frac{x}{x+y} \leq \eta_2, \quad 0 \leq y < \mu G^* \quad \text{and } x, y \text{ are integer} \]

If the congestion rate is \( \Delta = \frac{yd'}{xd} \), where \( d = v_u(t_1 + t_2) + \frac{v_2^2 - v_1^2}{2a_{\text{max}}} + d_1 \), \( d' = v_u(t_1 + t_2) \).

When \( \Delta = 0 \), that is, \( y = 0 \), then the road congestion level is four; when \( 0 < \Delta \leq 0.5 \), then the road congestion level is three; when \( 0.5 < \Delta \leq 1 \), then the road congestion level is two; when \( \Delta > 1 \), then the road congestion level is one. This is shown in the table below.

| Judgments based | \( \Delta = 0 \) | \( 0 < \Delta \leq 0.5 \) | \( 0.5 < \Delta \leq 1 \) | \( \Delta > 1 \) |
|-----------------|-----------|----------|----------------|------------|
| Congestion Level| four      | three    | two            | one        |

By 2020, the global vehicle networking industry standard system has basically been established. Therefore, taking 2020 as an example, it needs to find out when the number of manned cars and driverless cars can make the road congestion degree reach the minimum. According to the relevant data, by 2020, if residents of Q City are willing to give up ownership of private cars, then the number of manned vehicles
on the road will account for 2 to 30% of the total number of cars, and the total number of driverless cars will reach 50%. Therefore, the target planning equation is as follows:

$$\max \ G = \max \ x + y$$

$$0.2 \leq x / y \leq 0.3, \ 0 < y \leq 0.5, \ G^n_{2020} x + y < G^n_{2020}, \ y - x \geq 0$$

(13)

The car ownership of Q City in 2017-2025 is shown in Table 2. It can be seen from Table 2 that by 2020, the car ownership will be 358,815. Bringing $G_{2020} = 350$ into the equation (13), it can get: when $x = 43.75, y = 175$, the target equation is optimal.

Table 2 Car ownership/Quantity

| year | 2017 | 2018 | 2019 | 2020 |
|------|------|------|------|------|
| 10,000 vehicles | 223,7319 | 259,9394 | 302,0065 | 350,8815 |
| 2021 | 2022 | 2023 | 2024 | 2025 |
| 407,6662 | 473,6405 | 550,2918 | 639,3478 | 742,8162 |

According to the "Regulations on the Implementation of Road Traffic Safety of the People's Republic of China", the speed limit for urban roads is generally 40 to 60 kilometers per hour. In this paper, the speed of the front car after braking is $v_b = 40km/h$, the speed of the rear car before braking is $v_a = 60km/h$, and it is considered that the car is moving at a constant speed for a short period of time, then:

1. When the dry asphalt pavement is taken as $a_{max} = 6m/s^2$ and the rear car model is a manned car, the critical car safety distance is $d = 37.4134$. If the rear car is a driverless car, no matter what type of the front car is, the safe distance of the car will be shortened, and the reduced distance is $d' = 16.6667$. At this time, the congestion rate is $\Delta = 2.0125 > 1$, so the road congestion level is one level.

2. When the wet asphalt pavement is taken as $a_{max} = 4.5m/s^2$ and the rear car model is a manned car, the critical car safety distance is $d = 37.4134$. If the rear car is a driverless car, no matter what type of the front car is at this time, the safe distance of the car will be shortened, and the reduced distance is $\Delta = 1.7819 > 1$, at this time the congestion rate is $\Delta$ and the road congestion level is one level.

It can be seen from the above analysis that when the asphalt pavement is dry or wet, the degree of road congestion is one level. But this is only an ideal situation. If it is affected by certain factors, such as Q city residents do not completely give up the ownership of private cars, so that there are still people driving cars, just slowly decreasing, it will make $\Delta$ gradually smaller. The corresponding congestion rate will also gradually decrease.

4. Conclusion

Big data can provide decision support for traffic problem management, relying on digital technology, through the effective integration, processing and feedback of digital information, making traffic intelligence possible. Based on historical traffic data, the road congestion level is solved and given based on the number of manned cars and driverless cars set in 2020. Furthermore, it gives a reasonable solution to minimize road congestion when manned vehicles and driverless cars share road resources. In the future, if the driverless car makes breakthroughs in technology and law, the number of driverless cars will be an "explosive" growth. At the same time, massive traffic data will be generated. At this time, efficient and precise command and control under normal conditions and emergencies are important values and responsibilities of big data.

Acknowledgment

Thanks for the joint efforts of the team members.

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