Research on Ecological Driving Strategy of Urban Road Vehicles under Vehicle-road Collaborative Environment

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Abstract: With the increase of motor vehicles, the energy resources available for vehicles have become scarce. In view of the harmfulness of traffic emissions, energy conservation and emission reduction have become strategic goals for the development of the transportation industry. Guiding students to realize ecological driving and reducing vehicle fuel energy consumption and emissions have increasingly attracted the attention of researchers. We are supposed to do a research on signalized intersections at important nodes of urban transportation, use ecological driving to simulate the operation of bicycles and vehicle queues, establish an ecological driving model, and control energy conservation and emission reduction goals from multiple perspectives. This paper combines the ecological driving technology and micro fuel consumption calculation model under the vehicle-road collaborative environment to study the fleets within the signalized intersection. At the same time this paper proposes street signs, models, and case applications that can effectively reduce the average fuel consumption and parking times of the vehicles passing the signalized intersection to ensure the smoothness of operation at signalized intersections has been reduced, and rapid acceleration and deceleration operations have been performed. After verification, the establishment of the fleet's eco-driving model has great effectiveness.

1. Introduction
With the economic development and the increasing number of motor vehicles in recent years, the annual energy consumption of the transportation industry has become a rapid growth trend. At the same time, our dependence on traditional fossil raw materials, such as petroleum, is increasing. From the perspective of improving the current situation of vehicle energy use, it is one of the strategic development goals of China's current transportation industry to control emissions and achieve energy conservation and emission reduction.

2. Ecological Driving Theory in the Context of Vehicle-Road Collaboration
In the current realistic environment, the fuel consumption of vehicles is changed by improving vehicle fuel, improving vehicle performance, and affecting driving behavior. The use of road-coordination technology to guide the driver to change driving behavior to prevent idling and rapid acceleration and deceleration. At the same time, in order to reduce vehicle fuel consumption and emissions, the vehicle-road collaboration technology is used to simulate the ecological driving of the vehicle to develop an ecological driving model, which has achieved good results in energy conservation and emission reduction.

The theory of vehicle-road coordination at the signalized intersection and the vehicle-road coordination theory at the signalized intersection are cutting-edge theories in the field of intelligent transportation. A large number of technical studies on vehicle-road coordination have been conducted abroad. The United States has proposed that vehicle road coordination can improve vehicle driving
safety and reduce the impact of ground transportation on the environment. In Japan, it integrates various ITS functions, toll systems, and intelligent highway systems to establish an open public vehicle-road collaboration foundation platform [1]. China’s vehicle-road collaboration technology started relatively late. After continuous research and development, the vehicle-road collaboration technology was used to establish intersection speed guidance and path guidance simulation scenarios, which can effectively reduce the traffic on the road network. The average time of network traffic flow formation also has a good control effect. At present, vehicle-road coordination research is an important research direction of signalized intersections. Vehicle-road coordination technology is used to improve the safety factor and operating efficiency of vehicles passing through intersections. Combine vehicle speed induction to draw vehicle trajectory and signal timing, adjust the signal green light market as appropriate to reduce vehicle delays.

Research on eco-driving within signalized intersections is currently focused on improving vehicle energy use efficiency, forming environmentally-friendly speed driving, driving behaviors, etc., and removing additional structures to improve the accuracy of the preparation of traffic conditions in advance. This improves driving safety. Eco-driving technology can reduce the fuel consumption and emissions of vehicles at intersections. After research, the goals of acceleration, deceleration, magnitude, duration, and number of stops have been simplified. At the same time, the use of micro fuel consumption models, emission models, etc. can form a complete logical proof to minimize the amount of fuel consumed by vehicle traffic. Through the intersection of fuel consumption and carbon dioxide emissions, the optimization of the model significantly increased the formation time to varying degrees, effectively reducing emissions. For example, quantitative and qualitative analysis, vehicle driving behavior characteristics, based on the VSP emission model design is an ecological driving strategy, and simulation results are maintained for a long time to show that the strategy significantly reduces vehicle emissions. Based on VSP fuel consumption, calculation model, mathematical proof, ecological acceleration and deceleration, and constant-speed operating curve functions, the vehicle trajectory optimization method is established, and the vehicle ecological driving strategy is provided. The VISSIM simulation platform is used to verify the average fuel saving in the case of emissions and unlicensed pairs rate. By adjusting the objective function, it can effectively guide and control the energy saving and emission reduction of the eco-driving technology at intersections, and provide various theoretical research results for the composition of the eco-driving model in the vehicle-road collaborative environment [2].

3. Induced Running Trajectory of Signalized Intersections under Vehicle-road Coordination

⑴ The conditions of the vehicle pair study at the signalized intersection in the vehicle-road collaborative environment are explained, including the delay of information interaction between the vehicle and the infrastructure. In the vehicle-road collaborative environment, the vehicle speed, vehicle position, and signal between the vehicle and the infrastructure Time-sharing information sharing, vehicle trajectory and the situation of the intersection, the change of vehicles within the induction range and so on. For the vehicle-road collaborative environment, the identification of the fleet at signalized intersections must first identify the position, including the headway between vehicles. However, for speed identification and whether the vehicle speed is approximately the same, then we can deduct the head-to-head distance between the front and rear vehicles entering the induction range to identify the fleet, or use the speed and head distance to determine the fleet. This paper uses the two indicators of headway and instantaneous speed to identify the speed of vehicles in the vehicle-road cooperative fleet to identify vehicles at signalized intersections in the vehicle-road cooperative environment [3].

The first is the headway distance. At a certain time, the distance between the two head ends is the headway distance. The distance between the front car and the rear car is determined by the instant of the start line. The calculation formula is:
\[ F_T = \sum_i F_i \cdot D_i \cdot T \]

F is the total fuel consumption, D is the distribution frequency, and \( T \) is the total length of time in the calculation range. Then calculate the headway of the vehicle through the calculation formula, use the headway to make the preliminary identification of the fleet, and determine the standard headway. After a large number of vehicles appear at the intersection, the calculation and statistics of the simulation operation data are performed to comprehensively consider the headway distribution of the vehicles near the induction start line. The instantaneous speed is the speed of the vehicle at a certain moment. The moment the directly-selected vehicle induces its realization, the moment of the instantaneous speed of the vehicle and subsequent vehicles is determined to complete the identification of the fleet, and the headway is satisfied. As the base speed value, the relative error between the base speed value and the instantaneous speed is calculated.

On this basis, the subsequent vehicles are judged in the same way, the relative error range is determined, a large number of vehicle operating data are established, and the statistical analysis reaches the instantaneous speed difference between adjacent vehicles near the starting line.

2) The non-stop running time of the signalized intersection team in the vehicle collaborative environment. We set a scenario where the target team enters the induction range until the green light moment. Based on the state of the signal lights and the running conditions of the downstream vehicles, under various scenarios, such as the remaining time before the target team enters the induction range, the signal lights turn red, and the target team enters the induction range. Within the range, the time required for downstream vehicles to leave the intersection, and the target fleet entering the induction range, time, etc. at the moment of green light.

![Intersection Signal Phase](image)

According to the situation consideration, the traffic efficiency at the intersection is your induction target. The time when the team passes the intersection during the green light time, according to the setting of the induction range, the target team may pass the intersection at the green light time or when it reaches the parking line. In order to prevent conflicts with downstream vehicles, it may be necessary for the small fish to not stop at the green light time when they reach the parking line, the minimum time to pass the intersection, or after the target fleet enters the induction range, the downstream
vehicles do not pass the front intersection, has a certain impact on the operation of the target vehicle [4]. After the next green light starts, downstream vehicles will pass the intersection, and when they reach the parking line, the target fleet must avoid conflicts with downstream vehicles. At this time, the running time of the target vehicle may be longer than the stopping time, and the minimum running time of passing the intersection. In various scenarios, the target fleet enters the induction range. Based on the signal status and vehicle operating status, for the downstream vehicle operating status and different signal status, the running time range of the signalized intersection in the vehicle-road collaborative environment must be calculated. Discussion on the range of induced trajectory of vehicles at signalized intersections under the environment of vehicle-road coordination, to determine the feasibility of uniform induction of the target fleet. For the fleet of signalized intersections in the vehicle-road coordinated environment, maintain the current speed, pass through the signalized intersections at a constant speed, and take into account the ecological driving trajectory. Develop a uniform and minimal acceleration operation, so that the fuel consumption of the vehicle can be achieved by inducing the leading vehicle Speed-based. At the same time, the running speed of the vehicles in the target fleet is set. For the target fleet, the existing speed and uniform speed induction measures are adopted to introduce the retreat into the induction range, including the speed correction phase and the uniform speed operation phase. Discuss the range of the leading fleet of the target fleet, and perform the reverse trajectory of the leading fleet in different scenarios calculation. For example, the leading car passes by at the lowest possible speed, the value of the signal light changes, and so on.

4. Construction of Eco-Driving Model for Vehicles at Signalized Intersections in Vehicle-Road Collaborative Environment

(1) The VSP micro fuel consumption measurement and calculation model is relatively simple and easy to use. The fuel consumption calculation model based on power can reasonably explain the fuel consumption. The types of models include the CM1M model and the VT-CPF model, which are independent of the power in the car, comprehensively consider the driving function of the vehicle, and overcome air resistance. In the vehicle-road collaborative environment, the key part of the ecological driving trajectory selection is calculated to obtain the ecological driving trajectory that meets the expected value.

(2) The objective function of the vehicle ecological driving model is constructed. A large number of options are used to convert the energy saving and emission reduction goals. The vehicle-road cooperative induction strategy is developed. The fuel consumption objective function and the traffic efficiency function are used to determine the traffic efficiency at the intersection and the running time of the parking line as a response basis for traffic efficiency, a corresponding data model was designed [5].

(3) Construction of an eco-driving model for a signalized vehicle fleet at a signalized intersection. The specific implementation steps are to first identify the vehicle, generate a fleet number, then calculate the fleet induction running time range, determine whether the fleet accepts production driving guidance, determine the scenario of the induced vehicle, and follow the vehicle to calculate the leading vehicle. Invert the trajectory range, use genetic algorithm to calculate the objective function, and induce the fleet according to the selected ecological trajectory.

(4) The application of the eco-driving model at the signalized intersection vehicle uses the VISSIM simulation platform to collect vehicle operation data in the vehicle-road collaborative environment, set the fleet eco-driving model, and perform parameter calculations. The fuel consumption situation is based on the signalized intersection simulation platform to build a traffic simulation platform, which enables the simulation platform to describe the individual vehicle behavior in real time, accurately describe the geometric conditions of the signalized intersection, simulate the actual operation of the vehicle, and provide a visual interface for a output the driving condition data of the vehicle in real time.
5. Conclusion
So far, microscopic traffic simulation models have been applied in various fields of transportation research, and are commonly used simulation platforms. For the urban traffic road network and highway network simulation, you can simultaneously use the fields of traffic analysis and modeling to realize the simulation of vehicle operating conditions under various traffic conditions. Through the construction and calibration of the signalized intersection simulation platform, the signal distribution situation and vehicle traffic flow are determined, and finally the calibration results are followed. The universality of the simulation results is improved, and the characteristics of the traffic flow and driving behavior of module parameters in driving behavior are determined. The simulation and actual measurement results are compared before and after, and the total fuel consumption error is found to be within 10%, indicating that the parameter calibration of the simulation model basically meets the accuracy requirements.

Acknowledgment
Fund project: Basic scientific research-related expenses of provincial institutions of higher learning of Heilongjiang Province Education Department — Scientific Research on Ecological Driving Strategy of Signalized Intersection in the Environment of Vehicle-Road Collaboration (Project No.: 2018-KYYWF-1249)

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