Research on Eco-driving of Signalized Intersection Fleet in Vehicle-Road Cooperative Environment

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Study on Signalized Intersection Eco driving strategy in vehicle road coordination environment (Grant No.2018-KYYWF-1249)

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Abstract: In recent years, traditional motor vehicles have suffered increasingly severe constraints on energy resources. Coupled with the increasingly serious hazards of pollutants emitted by transportation, an important strategic goal for the development of China's transportation industry has been set for energy conservation and emission reduction. Vehicle-road collaboration technology is a cutting-edge technology in the field of intelligent transportation, which can guide drivers in ecological driving strictly in accordance with the actual traffic environment in which the vehicle is located. Therefore, researchers are paying more and more attention to how to reduce vehicle fuel consumption and emissions. Signalized intersection as an important node in urban roads needs to be studied. However, the focus of its research so far is on bicycles, and most researchers are indifferent to the situation in which vehicles are likely to run together within the intersection. In addition, when establishing an eco-driving model, most researchers will still focus on how to achieve energy conservation and emission reduction only from the perspective of reducing the number of parking times, and do not care about the essential attributes of fuel consumption. As a result, it is difficult for us to better control and quantify the overall implementation effect of the model. Based on this, it is very important to actively establish a corresponding fleet ecological driving model based on the fleet within the signalized intersection in the vehicle-road collaborative environment.

1. Introduction

Nowadays, China's social economy has developed by leaps and bounds compared with before, and the process of motorization is accelerating. Studies have shown that China's motor vehicle usage has been far ahead of other countries in the world for ten consecutive years, which has caused very serious motor vehicle energy dependence and traffic pollution problems. At the same time, according to the annual report on environmental management of motor vehicles issued by the environmental protection department, it is clearly stated that new energy vehicles have achieved long-term development in the market. However, China's transportation industry will still use traditional fossil fuels, such as petroleum, for a long time to come. The resource constraints faced by traditional fossil fuels are very severe [1]. The rapid depletion of traditional oil fields in the world is the general trend. The marginal cost of new oil fields such as deep sea and shale is relatively high. In addition, motor vehicle emissions caused by traditional vehicle energy have increasingly severely affected the atmospheric...
environment, and even threatened the health of the general public. In consequence, China's transportation industry needs to actively carry out energy conservation and emission reduction work. For this reason, many scholars have begun to study how to improve vehicle fuel and vehicle performance, and find ways to change vehicle fuel consumption. Among them, vehicle-road collaboration technology has attracted much attention.

2. Research on Guidance Trajectory of Fleet at Signalized Intersection in Vehicle-Road Cooperative Environment

2.1 Condition Description
The research related vehicles and infrastructure in signalized intersections in a vehicle-road collaborative environment are with the following conditions.
(1) Vehicles and vehicles, vehicles and infrastructure can better interact and share relevant information such as signal timing, vehicle speed and location in a vehicle-road collaborative environment, and we can ignore the delay between information interactions.
(2) The guidance range of a signalized intersection is the distance between the guidance start line and the stop line. Once the vehicle is guided, it needs to run according to the guided trajectory within the intersection.
(3) Emphasis is placed on the operation of cars and single-machine buses, and pedestrians, bicycles, trains, etc. may not be considered; the fleet of vehicles does not need to change lanes within the guidance range [2].

2.2 Fleet Identification
The so-called fleet mainly refers to those vehicles traveling at the same speed. Vehicles forming a fleet must meet the requirements of position and speed. Once the vehicle enters the induction range, in order to ensure the smooth induction, we need to complete the team identification work before entering. In order to better identify the vehicle fleet at signalized intersections in the vehicle-road collaborative environment, we can combine the two important indicators of headway distance and instantaneous speed to study the vehicle speed of the fleet from the perspective of simplicity of calculation.

2.3 Discussion on the Range of Induced Trajectory

2.3.1 Feasibility Judgment of Target Fleet Induction
For the signalized intersection fleet in a vehicle-road collaborative environment, we urgently need to choose an ecological driving trajectory, and strive to significantly improve operational efficiency and environmental protection benefits. Research has found that vehicle fuel consumption is the lowest when running at a constant speed or with minimal acceleration. If the target vehicle can maintain the current speed when passing a signalized intersection, no additional guidance is needed. For this purpose, we should actively discuss the possible conditions for the uniform induction of the target team.

2.3.2 Guided Trajectory Range of the Lead Vehicle of the Target Fleet
For vehicles running in a fleet with similar speeds and relatively close distances, the running characteristics of the following vehicles are deeply affected by the preceding vehicles. We can determine the induced trajectory of the lead vehicle of the convoy, and then we can formulate the induced trajectory of the entire convoy by determining the trajectory of subsequent vehicles.
3. Build An Ecological Driving Model

3.1 Based on VSP Micro Fuel Consumption Measurement Model
In recent years, people have paid more and more attention to the problems of vehicle fuel consumption and emissions, which also created good conditions for the emergence of micro-observation models. The micro-observation calculation model can accurately measure the fuel consumption of a single vehicle to a certain extent. Based on the measurement mechanism, the micro-observation calculation model can be divided into two types: the measurement model based on its own characteristic parameters and the vehicle operating state. Among them, the model based on its own characteristic parameters developed early and the measurement accuracy was high. However, it has a complex calibration range, and we must enter parameters with high accuracy. Therefore, models based on their own characteristic parameters have been widely used in the field of vehicle engineering, and the latter can accurately measure fuel consumption in the field of traffic engineering. In order to better subdivide the motion state of the vehicle itself, we also need to measure the model strictly in accordance with the relevant requirements. There are many simple and easy-to-use polynomial models in the driving mode. But they are indifferent to the difference in fuel consumption under different traffic conditions in the same driving mode. The calculation model based on power and fuel consumption can more reasonably explain the common CMEM and VT-CPFM models of fuel consumption, and its calculation is simple. The specific power of a motor vehicle is a power independent of the weight of the vehicle, and it is relatively easy to obtain and measure. It can also fully consider the changes in the kinetic energy of the vehicle and the work done by overcoming power such as air. In addition, it is also closely related to fuel consumption and emissions. At the same time, a large number of studies have shown that this parameter is the closest to the actual fuel consumption modeled parameter. It can be actively applied to the calculation of vehicle fuel consumption. This is also an important part of choosing an ecological driving trajectory in a vehicle-road collaborative environment. Whether we can accurately measure fuel consumption is directly related to the calculated expected value of ecological driving trajectory [3]. The physical meaning of VSP lies in the ratio between the output power and mass of a transient motor vehicle, and its parameter values are shown in Table 1.

| Vehicle Type | A     | B             | C   | m   | f_scale |
|--------------|-------|---------------|-----|-----|---------|
| Car          | 0.156461 | 0.00200193   | 6   | 1.4788 | 1.4788  |
| Bus          | 0.746718  | 0             | 0.00217584 | 9.06989 | 17.1    |

3.2 Constructing the Objective Function of the Fleet Ecological Driving Model
To ensure that the eco-driving trajectory found for the fleet can take into account both operational efficiency and environmental benefits. It is necessary for us to establish a multi-objective function to reflect the traffic efficiency of the intersection and the fuel consumption of the fleet. At the same time, the calculation of the micro fuel consumption calculation model is relatively complicated. Many studies have chosen to transform and simplify energy-saving and emission-reduction targets when formulating vehicle-road collaborative guidance strategies. As a consequence, when constructing the objective function, we still need to stand on the perspective of simplifying energy conservation and emission reduction targets.

3.3 Select Ecological Driving Trajectory Based on Genetic Algorithm
Genetic algorithm is mainly a simulation of genetic evolution and natural selection, dedicated to finding the optimal solution of the optimization algorithm to better explore and solve problems. Among them, there are many advantages such as global search, simplicity, and fast operation. Various non-linear and cumbersome problems can be effectively solved, so it is widely used in the field of...
optimization. In this way, some problem parameters can be encoded as genetic individuals, forming a set of feasible solutions to the problem composed of individuals. In order to better determine the individual's satisfaction with the objective function, we need to scientifically measure the individual's fitness. Only in this way can we take a variety of ways to simulate the biological evolution process and find a satisfactory solution to the problem.

3.4 Constructing An Ecological Driving Model of A Signalized Intersection Fleet in a Vehicle-road Collaborative Environment
Specifically, certain steps must be strictly followed in the process of constructing an ecological driving model for a signalized intersection fleet in a vehicle-road collaborative environment. That is, fleet identification, calculation of the time range of the fleet guidance operation, determination of whether the fleet can accept ecological driving guidance, identification of the situation of the guidance vehicle, calculation of the leading vehicle guidance trajectory, and calculation of the following vehicles. In addition, this can also calculate the guidance trajectory range of the second part of the lead vehicle and the second part of the following vehicle during the segment guidance of the fleet. Finally, we also need to use genetic algorithms to calculate the optimal solution of the objective function, and we need to strictly follow the selected ecological trajectory when inducing the fleet [4].

4. Case Application
In order to better collect vehicle operating data in a non-vehicle-road collaborative environment and measure the model parameters of fleet ecological driving, we can make full use of VISSIM simulation evaluation. Then, we need to combine various operating data and Python programming at signalized intersections to better identify the fleet and select the ecological driving trajectory of the fleet. On this basis, we also need to scientifically compare the acceptance, operation, and fuel consumption of its eco-driving trajectory to verify the scientificity and effectiveness of the model.

4.1 Build and Calibrate the Simulation Platform of VISSINM Signalized Intersection
With the help of the microscopic traffic simulation platform, various data can be easily and simply obtained. Moreover, these are difficult to obtain in real traffic scenarios, and the use of a simulation platform can collect vehicle operating data in a non-vehicle-road collaborative environment.

4.1.1 Choose A Traffic Simulation Platform
Based on the external interference that the vehicle receives within a certain range, we can use the traffic simulation platform to effectively simulate the actual operation of the following traveling vehicles. Moreover, we can better describe the individual behavior of vehicles such as the speed per second in real time based on future data requirements.

4.1.2 Build and Calibrate Signalized Intersection Simulation Platform
The signal cross simulation platform built with VISSIM5.2 version is a very typical cross shape. Each entrance includes a left-turn, right-turn, and straight lane, and the lane is about 500m long. After initially building a signalized intersection, we can combine the data input obtained from field investigations and calibrate platform parameters to ensure that the vehicle operating state is consistent within the simulation platform and the actual intersection.

4.2 Collect and Apply Vehicle Operating Data in A Non-vehicle-road Collaborative Environment

4.2.1 Collect and Analyze Various Simulation Data
In a non-vehicle-road collaborative environment, it is better to collect vehicle operating data such as the time when the vehicle reaches the induction starting line. We can set up the simulation platform for different random seeds and traffic flow.
4.2.2 Measure the Parameter Values of the Fleet Eco-driving Model
Considering that it is difficult for us to obtain various measured data such as the average fuel consumption of a single vehicle and the relative error range of the instantaneous speed. However, for normal application cases, we need to use simulation data to accurately measure the above parameters.

5. Suggestions and Outlook
Due to the limitations of time and technology, the current research has many shortcomings. For this reason, we need to actively carry out follow-up research and conduct in-depth exploration.

During the construction of the fleet eco-driving model, it is necessary to further simplify the downstream vehicles of the fleet and the subsequent vehicle trajectories except the front of the vehicle. This facilitates us to conduct in-depth research on its operating status and complete the scientific design of the fleet's ecological driving trajectory.

By analyzing the eco-driving model of the fleet in a saturated traffic state, we need to make a scientific comparison of the subsequent driving effects in different traffic states to determine the applicable conditions of the model.

To a certain extent, the fuel consumption of vehicles in the fleet is directly related to the objective function of the ecological driving model. In the future, we need to simultaneously compare the fuel consumption of a single vehicle under multiple energy-saving intensity targets. This will help us to further study the energy-saving effects of the model itself and better analyze the energy-saving and emission-reduction effects of the model.

The standard genetic algorithm can be used to better choose the ecological driving trajectory. For this reason, we need to further improve its computational efficiency and improve the genetic algorithm. We need to combine actual experience, predict and import optimization results, or use a variety of methods such as multi-population genetic algorithm to promote a significant improvement in optimization efficiency [5].

6. Conclusion
In recent years, many researchers have attached great importance to the use of vehicle-road collaboration technology in the process of vehicle ecological driving. Signalized intersection is a key node in urban road traffic, and it is also a key research area. However, so far this research has only focused on a single vehicle, and it is indifferent to the joint operation of vehicles with small distances within the range of signalized intersections. Furthermore, some scholars have actively and boldly applied eco-driving technology to the significant reduction of vehicle fuel consumption and emissions, without considering the nature of vehicle fuel consumption. Therefore, we can only stand one-sidedly from an empirical point of view and think that achieving the emission target is only in the reduction of the number of stops. In fact, if this method is used when formulating an eco-driving model, although certain energy-saving and emission-reduction effects can be achieved, the logic proves to be incomplete, and the model effect cannot be effectively controlled. To this end, we need to conduct in-depth research on the fleet driving model, and carefully select and construct ecological driving trajectories around the nature of fuel consumption. Finally, we need to further change the development of vehicle ecological driving technology aimed at reducing vehicle fuel consumption and emissions, and provide corresponding theoretical basis in the future vehicle-road coordination environment to better induce fleet ecological driving.

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