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The BFC Model of Analysis the Effect of Road Gradient on Car Fuel Consumption

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Abstract

The Model is Hundred kilometers fuel consumption model(BFC),

$BFC = (UFC_{io} + \alpha_3 \times RPM + \alpha_1 \times HP_{et} + \alpha_2 \times RPM \times HP_{et}) \times \frac{10^5}{v}$.

To obtain the the function relationship between the fuel consumption and speed, we have made the functional model standard by the data we got under experiment. And calculate the minimum fuel consumption speed by BFC function model. Set BFC function mode as target function .By the means of transforming the declivity to alter target function and using improved ACO ,We get the best speed of the lowest fuel consumption per 100KM.

Keywords: *Fuel consumption,Road grade,The best speed ,Ant colony algorithm.*

1. Problem description

In the past few years, the development of the electronic commerce makes logistics under pressure. Besides, compared with other transportation those directly face to the consumers, car transport plays a leading role. So we analyzed the subjective factors and objective factors affecting highway truck fuel consumption and study the relationship between the road gradient and vehicle speed, which does good to setting up the fitting equation of fuel consumption under different conditions. And then we use ant colony algorithm to calculate the minimum fuel consumption under the circumstance of different slope. And once the model turns out to be right, it can provide a reference data for the logistics company.

2. Problem analysis

It fuel consumption model to study the relationship between gradient and vehicle speed in order to get different fuel consumption under different speed.

Because of the influence of the environment ,equation obtained is not accurate enough so,we calculate different coefficient to weaken or eliminate the influence.In this way ,this equation can be used in different occasions.At the same time, collect the date researched in the certain sections in the process of study, and then deal with the data in a proper way, and the last step，check the reliability,making the result much more accurate.

The specific method to amend the coefficient as follows:

To begin with, we analyzed the subjective factors and objective factors affecting highway truck fuel consumption,and then,analyzed the calculation method and process of highway truck fuel consumption from the point of view of fuel consumption dynamics,the next,use the coefficient to amend to be much more accurate.

Concluded that highway trucks under the condition of actual operation fuel consumption ideas on the basis of calculating the maximum limit value, the road slope and speed independent calculation method of the influence of factors on the fuel consumption, on the basic operation conditions of fuel consumption calculation process was revised. Research shows the oil consumption of the sensitivity of the slope and the speed correction factor analysis, calculation method, and established the basic operation conditions truck fuel consumption calculation model; analyses the calculation error under different slope and speed; at the same time, presents a method for estimating the highway conditions of fuel consumption.

After checking，we come to the conclusion that the model we build is correct and reasonable.And the most important is that the model can be used in different occasions and has a good application value.Besides, the research has certain guiding significance to establishing other types of vehicle fuel consumption calculation model.

3. Radiation Establish Hundred kilometers fuel consumption model

In 5.1, we establish the theory of fuel consumption model is the fuel consumption per unit time, but given the unit fuel consumption and the best fuel consumption is different two concepts, Its minimum unit fuel consumption under a certain speed, but the car may need more time to exercise the same distance. Its Hundred kilometers not fuel-efficient, the social value is not necessarily high. In the process of motor transport, the need to consider is the best fuel economy speeds, with hundreds of kilometers fuel consumption to evaluate economic speed, only consider the factor of time in the unit fuel consumption, hundreds of kilometers fuel consumption model is set up.

$$BFC = UFC \times \frac{10^5}{v} \quad (1)$$

$$BFC = (UFC_{io} + \alpha_3 \times RPM + \alpha_1 \times HP_{et} + \alpha_2 \times RPM \times HP_{et}) \times \frac{10^5}{v} \quad (2)$$

4. Ant colony algorithm to solve the optimal speed

According to the function calibration and solving in the part 5, we can get (6-2) a
hundreds of kilometers of fuel consumption and the speed of the continuous function, can use continuous function optimization ant colony algorithm to solve the more accurate the best speed.

4.1. Introduce the Ant colony algorithm

ACO is by Italian scholar M.Dorigo and other people put forward in 1991, the first meeting of artificial life, The principle of the algorithm is based on the ant in the process of in search of food, can be in the release of a pheromone on the path to walk, the amount of released pheromone and is inversely proportional to the length of the path. From these pheromones, other ants can get certain guiding significance on the path selection. When a path through the more the number of ants,the greater all ants stay on the path of pheromone concentration is, the greater the subsequent ants choosing this path of probability is, the greater the as more ant chooses the path, the pheromone intensity will gradually increase, the selection process can form a positive feedback mechanism of pheromone, ants can quickly find the food, is by the positive feedback mechanism.

As a new kind of random search algorithm, the earliest is applied to solve the traveling salesman problem (TSP), and later succeed solved other combinatorial optimization problem, Such as: vehicle routing problem (VRP), shop scheduling problem (JSP), quadratic assignment problem (QAP), etc.

The algorithm is a mathematical model for solving discrete problem, so in to the broader application of discrete optimization problems. For function optimization is a continuous optimization problem, which is difficult to directly use ant colony algorithm for function optimization, but the mechanism of ant colony algorithm adopts a distributed parallel computing, has stronger robustness, easily combined with other algorithms, through exploring in recent years, many scholars put forward many improved algorithms, such as: network optimization algorithms, such as continuous ant colony optimization (CACO) algorithm. While in the optimum solution for continuous function has made rapid progress, but still there are easy to fall into local optimal solution, slow convergence speed of the shortcomings. Using the algorithm to solve the optimal speed, can effectively expand the search scope to avoid falling into local optimum problem, To a certain extent, improve the quality of the optimization and convergence efficiency, able to accurately solve every slope corresponds to the optimal speed.

4.2. The realization of the ant colony algorithm

Ant colony algorithm can be thought of as three process interaction: The initialization parameter, The ant build solution, Update the pheromone. The first step, mainly pheromones and initialization parameters; The second step, each ant probability rule under a full path, transition probability is a function of branch pheromone; The third step, the pheromone update, There are two principles of its update:

(a) Pheromone volatilization, it helps to search a better solution, "forgotten" the previous poor solution, pheromone volatilization of formula is as follows:

$$\tau_{ij} \leftarrow (1-\rho)\tau_{ij} \quad (3)$$

τ_{ij} represent the size of the pheromone on the path, ρ represent a pheromone volatilization coefficient, $1-\rho$ represent the residual coefficient of the pheromone.

(b)The increase of the pheromone, it is proportional to the ant path length, Formula is as follows:

$$\tau_{ij} \leftarrow \tau_{ij} + \sum_{k=1}^{m} \Delta\tau_{ij}^{k} \quad (4)$$

m represent the number of ants, $\delta\tau_{ij}^{k}$ represent ant of k in the path pheromone increment on the ij , τ_{ij} represent The size of the pheromone on the path to ij .

This paper is a problem of solving a global minimum in optimization function, $v_{\min} \in V$. meet for any point in the interval , $f(v) \geq f(v_{\min})$, the solution space is a representation of a regional rather than a discrete points, so in the continuous space optimization problems to solve, choose way ants on the basis of all point is not the size of the pheromone, but an area of the influence of the pheromone of ant.

4.2.1. Determine ant colony initial position, and pheromone initialization

When solving the optimal speed, hundred kilometers fuel consumption is a continuous function of speed. $BFC = \min f(v)$, $v = (v_1, v_2, \ldots v_n)$,value range $[S,E]$, m represent the number of ants, In the optimization space randomly placed within m ants, as the starting point of each ant search, the length of each phase are:

$$L(j) = \frac{E(j)-S(j)}{m}, j = 1,2\ldots n \quad (5)$$

Initial position distributions of the ants are as follows:

$$v_i = (rand(S(1), E(1)), rand(S(2), E(2)), ...rand(S(n), E(n))) \quad (7)$$

$rand(S(j), E(j)$ is a random number in interval $[S(j), E(j)]$.

According to the distribution of ants are located, according to find the smallest problems in determining the initial pheromone of ant:

$$\Delta t(i) = ka^{-f(v_i)} \quad (8)$$

$a > 1$ ($a = e$), for the objective function $f(v_i)$ value is smaller, v_i left in place of the more pheromone.

4.2.2. Ants moving rules

Each ant on the completion of the search, according to the rules of the corresponding mobile for the next search, In this paper, the improved ant colony algorithm, ant colony in the completion of the cycle, will get the optimal solution in this cycle for other ants of the next cycle starting position. Ants moving rules into two parts: One is not to find the optimal solution in the last cycle the ants move to the optimal solution; The other part is to point to to get the optimal solution of ants in the field to search the optimal solution, has got a better solution. Below these are given to two movements rules:

Rule 1: On completion of the cycle, the ants will to find the optimal solution in the loops ants to transfer, transfer probability formula is as follows:

$$p(i, best) = \frac{e^{(t(best) - t(i))}}{e^{t(best)}} \quad (9)$$

$$v_i = \begin{cases} v_i + \lambda(v_{best} - v_i), p(i, best) < p_0 \\ v_i + rand(-1,1) \times L, other \end{cases} \quad (10)$$

$0 < p_0 < 1$, $0 < \lambda < 1$ 。

Rule 2: In the process of the last cycle to obtain the optimal solution of the ants, in search for the solution of the field, if the new position better than the original position, the most value to replace the original position; On the other hand, is to leave the place. Search step should be to reduce with the increase of the number of iterations, so that in future search will be able to get with accurate solution of mobile formula is as follows:

$$v(best) = \begin{cases} v_{tbest}, t(tbest) > t(best) \\ v_{best}, other \end{cases} \quad (11)$$

v_{tbest} represent the current optimal solution

Mobile step length formula is as follows:

$$v_{best} = \begin{cases} v_{best} + \omega \times dv \\ v_{best} - \omega \times dv \end{cases} \quad (12)$$

4.2.3. The pheromone update rule

After completing the search, update the pheromone of ant i, update the rules as follows:

$$t(i) = \rho \times t(i) + \Delta t(i) \quad (13)$$

ρ represent a pheromone volatilization coefficient, $0 < \rho < 1$, $\Delta t(i) = ka^{-f(v_i)}$.

4.2.4. Improved ant colony algorithm process flow:

(1) According to determine the number of ants m and the maximum number of cycle I, Determine the scope of variables, according to the formula (5) to (8) initialization ant colony location and the size of the pheromone.

(2) An ant according to the size of the pheromone of location, search out of the loop gain the best solution v_{best} of the ants.

(3) Each ant to earlier to find the best solution as a starting point, according to the formula (9) to (10).

(4) Get the best solution v_{best} of the ants, in formula (11) to (12) in the near field to search, update the position of the current solution.

(5) All the ants in the completion of the search, according to the formula (13) updating pheromone. Repeat step (2) until meet its stop condition.

4.5. Using ant colony algorithm to calculate the results

In the uphill, fuel consumption will change when we use different gear, so, in order to more accurately to find the optimal speed under the minimum fuel consumption, consider grade under the different gear, the optimal speed. Due to the change of the slope will affect slope resistance calculation, the calculation of gear could be affected the rotational speed of engine. Even if the slope and the gear changes, but still meet type 2. You only need to change after the slope of resistance GF and the motor speed RPM into the formula 2. We will change after the function as the target function, using ant colony algorithm to solve.

5. Model Improvement and Extension

Solving the model applied the improved ant colony algorithm, with high robustness, the results more accurate, with good generalization. According to the car's dynamics and functional balance principle, we established a theoretical model about fuel consumption to improve the performance and reliability of Off-site use. If add the influence of the bending resistance in fuel consumption model theory, can be more comprehensive consideration question, solving the results will be more accurate.

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