An Energy Consumption Model of Electric Vehicle based on Neural Network

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Abstract. With global warming, energy crisis and air pollution in the city is increasing, energy saving and emission reduction situation facing traffic field is becoming more and more serious. Combined with the research results related to the establishment of energy consumption model of ideas, this paper determines the energy consumption of electric vehicle model by using the running data. At the same time, the acceleration will be divided into acceleration and deceleration and hook speed condition according to the running condition for the detailed description of the relationship between energy consumption rate and the electric vehicle speed and acceleration, and the energy consumption models are established. The energy consumption rate showed a rising trend with increasing acceleration at the same speed. From the overall analysis, the peak energy consumption rate in speed and acceleration are part of the larger, and energy consumption rate has remained low when the acceleration is less than or equal to zero parts.

Keywords: Energy Consumption Model, Electric Vehicle, Neural Network, Energy Consumption Characteristics

1. Introduction
With global warming, energy crisis and air pollution in the city is increasing, energy saving and emission reduction situation facing traffic field is becoming more and more serious [1]. The development of city low carbon transportation system with low energy consumption, low emission and low pollution characteristics has become the inevitable choice to realize the sustainable development of the city traffic [2-3]. In the process of using zero pollution, low noise and high energy efficiency, the role of electric vehicles in the construction of low carbon traffic is expected in the cities of various countries [4-6]. Other pollutants such as sulfur and particulates are also significantly reduced. In view of the advantages of electric vehicles, the development strategy of new electric vehicles has been promulgated and implemented by the countries and regions represented by the United States, Japan and the European Union [7-9]. In the coming years, it will be a strategic opportunity for research and industrialization of electric vehicles. The national programme for climate change also announced measures to encourage the production and consumption of hybrid electric vehicles and pure electric vehicles [10-11].
However, due to the short mileage of electric vehicles and lagging behind in charging facilities, the promotion and use of electric vehicles have been severely restricted [12]. To improve the endurance of the electric vehicle by its own technical research and development, it is of great significance to improve the electric vehicle’s mileage by planning energy saving path and improving driver's driving control mode, which is very important for the promotion of electric vehicle at this stage [13].

2. Energy Consumption Model

Suppose an integral operator is $K$. Let $K$ be a compact operator from Banach space $V$ to $V_n$. Thus equation (1) can be written as an operator scheme expression,

$$Ku = f$$

(1)

The steps of model design are as follows.

STEP1. Choose a sequence $V_n \subset V (n \geq 1)$, where the dimension of $V_n$ is $N$, in a finite dimensional subspace.

STEP2. Choose Haar wavelet basis $\{h_i\}_{i=1}^{N}$ in $V_n$; suppose $u_n \in V_n$ is the numerical value of equation (9), and then use $u_n$ to approach $u$. $u_n(x)$ can be expand into equation (2), where $c_i = \langle u_n(x), h_i(x) \rangle$ holds and $\{c_i\}_{i=1}^{N}$ is unknown.

$$u(x) \approx u_n(x) = \sum_{i=1}^{N} c_i h_i(x)$$

(2)

STEP3. Use the traditional Galerkin method. Equation (3) is obtained by substituting equation (2) into integral equation (1). When the remainder term $r_n$ in equation (3) is zero, $u_n(x) = u(x)$ is obtained. To conveniently get a more accurate numerical solution, $r_n(x)$ needs to be as close to zero as possible.

$$r_n(x) = \sum_{i=1}^{N} c_i \frac{1}{\Gamma(\alpha)} \int_{0}^{1} k(x, \tau)(x-\tau)^{\alpha-1} h_i(\tau) d\tau - f(x) = Ku_n(x) - f(x)$$

(3)

STEP4. Suppose $V = L^2[0,1]$, and let $N = 2^J$ be the wavelet resolution; to meet the requirement of Galerkin method, let $\langle r_n, h_j \rangle = 0$, where $j = 1, 2, \cdots, N$; and then with equation (3), a system of linear equations, i.e. equation (4), can be obtained.

$$\sum_{i=1}^{N} c_i \langle Kh_i, h_j \rangle = \langle f, h_j \rangle, \; j = 1, 2, \cdots, N$$

(4)

The model with $r$ input and $m$ output is as follows.

$$y_m(t) = N[y_m(t-1), y_m(t-2), \cdots, y_m(t-n_1), u_r(t), u_r(t-n_2), \cdots, u_r(t-n_k-n_b+1) + e_m(t)]$$

(5)
Among them, \( y_n(t) = \begin{bmatrix} y_1(t) \\ \vdots \\ y_m(t) \end{bmatrix}, u_n(t) = \begin{bmatrix} u_1(t) \\ \vdots \\ u_m(t) \end{bmatrix}, e_n(t) = \begin{bmatrix} e_1(t) \\ \vdots \\ e_m(t) \end{bmatrix} \) is the system output, input and modeling error. \( n_a \) and \( n_b \) represent the output and input time matrices of the time. \( n_k \) is a time delay matrix from each input to the output.

3. Simulation of Energy Consumption in the Model

The actual driving mode of outdoor roads can provide a more realistic operation environment. The test results are more accurate, but the application cost is high and the adjustment is more difficult. At the same time, a lot of data are needed to cover all kinds of driving states of vehicles. The basic parameters of the electric vehicle used in this article are shown in Table 1.

**Table 1. Vehicle performance**

| Dimension parameter | Vehicle size (mm) | 4130×1750×1690 |
|---------------------|------------------|-----------------|
| Weight parameter    |                  |                 |
| curb weight (kg)    | 1580             |
| Front axle load (kg)| 805              |
| Rear axle load (kg) | 700              |
| Dynamic performance index |                  |                 |
| Maximum speed (km/h) | >100             |
| Acceleration time (0-50km/h) | <10             |
| Acceleration time (50-100km/h) | <8              |
| Maximum climbing degree | >20%             |
| Maximum reversing speed | 12km/h         |
| Economic performance index |                  |                 |
| Driving mileage (km) | >120             |
| Battery parameters  |                  |                 |
| Capacity (Ah)       | 65               |
| Voltage (V)         | 300              |

The data collected is shown in Table 2.

**Table 2. The collecting raw data**

| Serial number | Accumulative time (s) | Speed (km/h) | Voltage (V) | Current (A) |
|---------------|-----------------------|--------------|-------------|-------------|
| 0             | 0                     | 0            | 380.2       | 1.6         |
| 1             | 0.1                   | 0            | 380.0       | 1.53        |
| ...           | ...                   | ...          | ...         | ...         |
| 1000          | 100                   | 10           | 373.2       | 5.05        |

In order to realize optimum energy consumption in model, the stimulation of experiment is carried out. Having a model stimulation by Matlab needs to store vehicle performance data and schedule task. Time internal of data sample is 0.1s and central time of travelling is \( t_0 = 15s \). The common tool is the neural network, and its structure is like Figure 1.
Figure 1. The model based on neural network

The relationship between the energy consumption characteristics and time is shown in Figure 2, Figure 3 and Figure 4.

Figure 2. The relationship between the energy consumption characteristics and time from 0 to 0.15

Figure 3. The relationship between the energy consumption characteristics and time from 0 to 0.25
Figure 4. The relationship between the energy consumption characteristics and time from 1 to 2.5
The results show that the way of slow acceleration is taken to save more energy in the acceleration starting and accelerating process of moving scene. the way of slow deceleration is taken to save more energy consumption in braking and deceleration scene during driving. In vehicle route 500m scene, the hook speed and deceleration can be taken in energy saving uniform running at different speeds. In order to save energy, the experimental vehicle should try to follow the economic driving speed of about 40km/h.

4. Conclusion
The energy consumption rate showed a rising trend with increasing acceleration at the same speed. From the overall analysis, the peak energy consumption rate in speed and acceleration are part of the larger, and energy consumption rate has remained low when the acceleration is less than or equal to zero parts.

Acknowledgments
This work was financially supported by Science and Technology Research Project of Jiangxi Provinical Education Department "Face recognition based on Embedded Zerotree Wavelet" (Grant No. J61635).

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