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Research on the Prediction of Nickel-metal Hydride Battery Capacity based on Artificial Intelligence Algorithm

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With the development of the modern society, nickel metal hydride battery has been paid attention to by scholars and manufacturers. Nickel metal hydride battery is an ideal power source for hybrid electric vehicles due to its high specific energy, high specific power and zero pollution. At the same time, the research on the prediction of nickel metal hydride battery capacity has become the focus of scholars and manufacturers. As an important artificial intelligence algorithm, the neural network algorithm has attracted the attention of scholars. In this paper, we put forward the improved BP neural network prediction algorithm in order to study the prediction of nickel metal hydride battery capacity. In the end, the improved BP neural network is used to predict the of nickel metal hydride battery capacity. After the experiment, we find that the improved method has good prediction accuracy.

1. Introduction

Since entering in twenty-first century, people's living environment is getting higher and higher and the strategic thinking of sustainable development has been deeply rooted in the hearts of the people. However, the energy problem has become the bottleneck of social development. With the increasing of vehicles, the problem of exhaust emission becomes the focus of society. At the same time, vehicle resources and gasoline prices are rising. Due to the many advantages of new energy, the research of electric vehicle has become the mainstream of the development of automobile industry. Electric vehicle is a kind of zero pollution emission vehicles with battery. As a new type of high energy storage battery developed in recent years, nickel metal hydride battery has the characteristics of high specific power, no pollution and high safety. After extensive verification, nickel hydrogen batteries have been large-scale production and occupy a huge share of the market. At present, the main performance of power batteries can be seen from table 1 as follows

Table 1: The main performance of power batteries

Battery type	Mass specific energy	Mass specific power	Cycle times	Safety	Economic efficiency	Environmental friendliness	Comprehensive performance
Lead-acid battery	30-35	80-110	200-300	High	High	Low	Poor
Nickel-cadmium battery	33-47	45-65	500	High	High	Low	Poor
Nickel metal hydride battery	40-60	800-1350	>1000	High	High-medium	High	Good
Lithium-ion battery	110-130	800-1300	>1000	Low	Low	Medium	Poor
Lithium iron phosphate battery	85-100	600-1300	>1000	Medium -low	Medium - low	Medium	Medium -poor

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An artificial neural network prediction model was used to research the temperature of Ni-MH (Fang et al., 2012). The researchers used the linear regression method to predict the model at different temperatures. The model predicted battery temperature under different temperatures of 50 degrees, 60 degrees, 70 degrees and achieved excellent prediction results. A new thermal model was used to research on the nickel metal hydride battery fast charging thermal behavior at constant currents (Peyman et al., 2014). The numerical model was established and the experimental results showed that when the charging current increased, the charging efficiency decreased. A distributed model was proposed for nickel metal hydride battery of new La2MgNi9 alloy (Gabis et al., (2015)). This mathematical model was used to describe the discharge of nickel metal hydride battery. The design and implementation of the nickel metal hydride battery remaining capacity system were described in detail (Li, 2004). The results showed that the system could predict and correct the state of the battery. The system not only improved the prediction accuracy, but also improved the performance of the energy management system. The dynamic model of the internal voltage and the charging current was established. A method for predicting the charging power of the battery by the internal pressure during the battery charging process was proposed (Liu, 2016). The method could realize the fast charging of the battery with high efficiency.

Neural network was an important branch of artificial intelligence. The neural network is the method and theory of Intelligent Computing based on the research of the intelligent information processing ability of the human brain (Mircea et al., 2017). Artificial neural network is established by artificial neural topology and simulates the human brain to learn knowledge and solve the problem. The neural network has an extensive application field in the power grid (Hu et al., 2016), fusion (Wang et al., 2016) and so on. BP neural network uses the Sigmoid function as a transfer function with a strict structure, operability and other characteristics (Wang et al., 2013). BP neural network can achieve output and input nonlinear mapping.

In this paper, we propose an improved BP neural network to predict the capacity of nickel metal hydride battery. The traditional BP model is improved and the combined with the GA to form a new improved algorithm. The first part of this paper is the introduction. The first part introduces the basic information. The second part is the working principle of nickel metal hydride battery. The third part introduces the traditional BP neural network. The fourth part is the improved BP neural network algorithm. In the fourth part, we propose a new BP neural network algorithm which is combined with the GA. The fifth part is the experiment and the last part is the conclusion.

2. Working principle of Nickel metal hydride battery

With the continuous development of battery technology, there have been many batteries, such as lead-acid batteries, lithium batteries, etc. Ni-MH battery capacity is higher than the general battery and can eliminate environmental pollution of heavy metal elements. Nickel metal hydride battery is composed of a positive electrode of nickel metal hydride, hydrogen storage alloy and alkaline electrolyte. At the same time, the electrochemical characteristic of the Ni-MH battery is similar with the nickel cadmium battery. Nickel metal hydride battery can replace the nickel chromium battery.

During charging, the chemical reaction of the anode is as follows:

$$Ni(OH)_2 + OH^- \rightarrow NiOOH + H_2O + e^- \tag{1}$$

The chemical reaction of the cathode is as follows:

$$M + xH_2O + xe \rightarrow MH_x + xOH^- \tag{2}$$

M is hydrogen storage alloy and *MH* is the hydrogen storage alloy adsorbed hydrogen atom.

Nickel hydrogen battery anode uses hydrogen storage alloy. The hydrogen diffuses into the surface of the electrode during discharge and generates H_2O or H^+. Battery anode is *NiOOH*. Ni^{3+} is reduced to Ni^{2+} and generates $Ni(OH)_2$.

When the nickel metal hydride battery is charged later and overcharge, the reaction is

Anode:

$$4OH^- \rightarrow 2H_2O + O_2 + 4e^- \tag{3}$$

Cathode:

$$4MH + O_2 \rightarrow 4M + 2H_2O \tag{4}$$

When the battery is discharged, the reaction is

Anode:

$$2H_2O + O_2 + 4e^- \rightarrow 4OH^- \tag{5}$$

Cathode:

$$MH + OH^- \rightarrow M + H_2O + e^- \tag{6}$$

It can be seen that the charge and discharge of nickel metal hydride battery is an iterative process that the hydrogen atom transfers from one electrode to another. In addition, when the batter is overcharging, oxygen oxidation occurs on the electrode; when the battery is discharging, hydrogen elimination reaction occurs. The nickel metal hydride battery has good resistance to overcharge and overdischarge ability.

3. BP neural network

The input node of BP neural network is x_j, hidden node is y_i, output node is O_i and expected output of output node is t_j

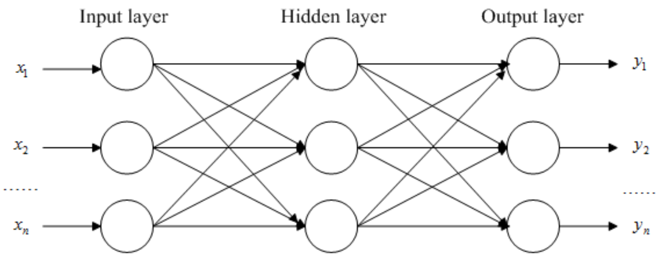

Figure 1: Network model structure

The output of the hidden node is

$$y_i = f(\sum_j w_{ij} x_j - \theta_i) = f(net_i) \tag{7}$$

Where $net_j = \sum_j w_{ij} x_j - \theta_i$.

Output of the output node is

$$O_l = f(\sum_t T_{li} y_i - \theta_i) = f(net_i) \tag{8}$$

Where $net_l = \sum_i T_{li} y_l \theta_l$.

The error formula of the output node is

$$E = \frac{1}{2}\sum_l (t_l - O_l)^2 = \frac{1}{2}\sum_l (t_l - f(\sum_i T_{li} y_i - \theta_l))^2$$
$$= \frac{1}{2}\sum_l (t_l - f(\sum_i T_{li} f(\sum_j w_{ij} x_j - \theta_i) - \theta_l))^2 \tag{9}$$

Then

$$\frac{\partial E}{\partial T_{li}} = -(t_i - O_l) \cdot f'(net_l) y_i \tag{10}$$

The error of the input node is

$$\delta_l = -(t_l - O_l) \cdot f'(net_l) \tag{11}$$

Then

$$\frac{\partial E}{\partial T_{li}} = -\delta_l y_i \tag{12}$$

The error of the hidden node is

$$\delta_i' = f'(net_i) \cdot \sum_l \delta_l T_{li} \tag{13}$$

Then

$$\frac{\partial E}{\partial T_{li}} = -\delta_i' x_j \tag{14}$$

Correction value of weights are ΔT_{li} and Δw_{ij} .
For the output node

$$\Delta T_{li} = -\eta \frac{\partial E}{\partial T_{li}} = \eta \delta_l y_i \tag{15}$$

$$\delta_l = (t_l - O_l) \cdot f'(net_l) \tag{16}$$

$$T_{li}(k+1) = T_{li}(k) + \Delta T_{li} = T_{li}(k) + \eta \delta_l y_i \tag{17}$$

For the hidden node

$$\Delta w_{li} = -\eta' \frac{\partial E}{\partial w_{li}} = \eta' \delta_i x_j \tag{18}$$

$$\delta_i = f'(net_l) \cdot \sum_l \delta_l T_{li} \tag{19}$$

$$w_{lj}(k+1) = w_{ij}(k) + \Delta w_{ij} = w_{ij}(k) + \eta' \delta_i' x_j \tag{20}$$

4. Improved BP neural network

The commonly BP algorithm uses the error back propagation algorithm based on the steepest descent method. The convergence speed of BP algorithm is slow. Moreover, the network performance will be worse with the increase of samples. In order to get the global minimum point of the BP algorithm, we introduce the smoothing coefficient ϕ. If the symbol of the correction quantity of time *k* is different from time *k*-1, smoothing coefficient ϕ will make the correction quantity smallest. At the same time, we introduce the forgetting factor φ. So that the BP network can take into account the connection state at the same time

$$\Delta T_{li}(k) = \eta \delta_l y_i + \phi \Delta T_{li}(k-1) + \varphi \Delta T_{li}(k-2) \tag{21}$$

$$\Delta w_{li}(k) = \eta \delta_l x_i + \phi \Delta w_{li}(k-1) + \varphi \Delta w_{li}(k-2) \tag{22}$$

GA is a kind of global search and optimization method which is based on the theory of evolution and genetics. The algorithm is efficient, practical and robust. The steps of the genetic algorithm are as figure 2.
Because the GA has the characteristics of no gradient information, global search and so on, it can enhance the ability of BP model by using the genetic algorithm to optimize the weight and the structure. Through the fusion of BP neural network and genetic algorithm, the fusion algorithm has the advantages of seeking the global optimal solution.
In this paper, we combine the BP neural network and genetic algorithm and propose an improved BP model prediction algorithm. The specific steps are as follows.
Step 1. We compute the node distribution interval of the hidden layer and determine the maximum genetic algorithm evolution algebra. The algorithm input layer node number, output layer nodes and algorithm stop

condition is determined according to the solution of the problem. Finally, we populate the initialization of genetic algorithm.
Step 2. The neural network structure and the weight and the value are coded according to the recursive coding mechanism. The nodes, weights and thresholds of the hidden layer of neural network are obtained.
Step 3. BP network is trained.
Step 4. We compute the individual fitness.
Step 5. The population is on group selection and crossover operation
Step 6. The population mutation operation is made and the next generation of groups are gotten.
Step 7. Training stop condition is judged. If it meets, algorithm outputs maximum fitness; if not, return to the Step 2.

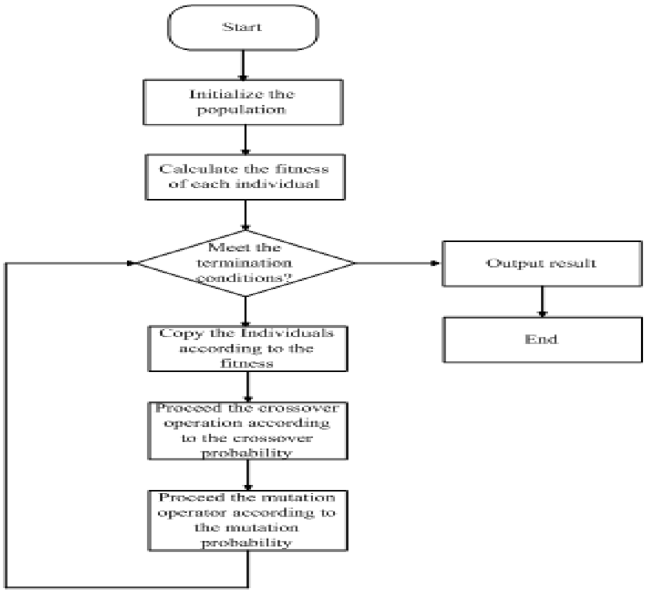

Figure 2: Flow chart of genetic algorithm

5. Experiment

In this paper, we conduct simulation experiments in order to verify the feasibility and effectiveness of the improved BP neural network prediction model in the nickel metal hydride battery capacity prediction. To calculate the capacity of nickel metal hydride battery accurately, we introduce SOC. SOC is an important parameter to describe the state of the battery. The SOC is defined as the ratio of the remaining capacity of the battery to the battery capacity:

$$SOC = QC/CI \tag{23}$$

Where, *QC* is battery remaining capacity and *CI* is capacity of a battery to discharge at constant current.
As can be seen from the figure 3, the improved BP neural network prediction algorithm can effectively forecast the predicted value of the SOC. The curve of the predicted value and the true value is coincident. These show that the model has high accuracy.
At the same time, we compare the prediction results of other prediction algorithms.
As can be seen from table 2, the average relative error of the improved BP algorithm proposed in this paper is 0.37. The average relative error of LSSVM algorithm is 0.56. The average relative error of genetic algorithm is 0.53 and grey algorithm is 0.86.

Table 2: The prediction results of other prediction algorithms

Algorithm	Average relative error
Improved BP neural network algorithm	0.37
LSSVM	0.56
genetic algorithm	0.53
Grey algorithm	0.86

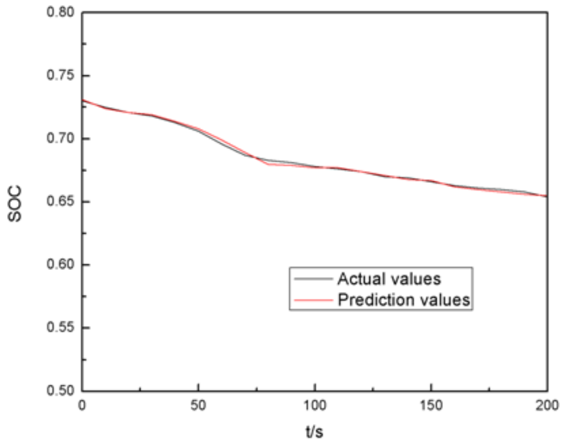

Figure 3: Prediction results of improved BP neural network

6. Conclusion

With the development of society and technology, the energy of the earth is decreasing and people have realized the importance of energy. In the context of Scientific Outlook on Development, environmental issues are placed in a very important position. Due to the advantages of high specific energy, long service life, no pollution and so on, nickel metal hydride battery has become the first choice of battery for electric vehicles.

In this paper, an improved BP neural network prediction algorithm is proposed to predict the nickel metal hydride battery capacity. The experimental results demonstrate the accuracy of algorithm in this paper. The primary coverage includes: (1) introducing the research background of the paper (2) introducing nickel metal hydride battery working principle and BP neural network algorithm (3) proposing improved BP neural network prediction algorithm and use this algorithm to predict the nickel metal hydride battery capacity. The experimental results show that the improved BP model prediction algorithm can get more accurate prediction results compared with the traditional prediction algorithm.

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