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An improved genetic-backpropagation neural network for state of charge estimation of lithium-ion batteries.

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An improved genetic-backpropagation neural network for state of charge estimation of lithium-ion batteries

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***Abstract*. The state of charge estimation with high precision plays an important role in the usage of lithium-ion batteries in electronic vehicles. An improved genetic-backpropagation neural network (GA-BPNN) is proposed to predict the state of charge with high precision under complex working conditions. Specifically, the elite retention strategy is introduced to genetic operations to enhance the efficiency of the algorithm. Moreover, a further performance comparison of the improved GA-BPNN is achieved to prove its effectiveness. The experimental results show that the accuracy of the improved GA-BPNN is 7.92% and 6.71% under BBDST and DST working conditions, which are higher than that of traditional methods.**

Keywords-backpropagation; genetic algorithm; elite retention strategy; state of charge; lithium-ion batteries

I. Introduction

With the growing awareness of environmental protection, recyclability and efficiency are important indicators for environmentally friendly applications[1, 2]. Thus, it is very important to monitor the status of lithium-ion batteries[3]. One of the important parameters is the state of charge (SOC), which can reflect the status of lithium-ion batteries directly[4]. For SOC estimation, including the Ampere-hour (Ah) integral method, model-based estimation methods, and data-driven estimation method [5]. This paper proposed the elite retention strategy to reduce the convergence time, which keep 30% population with best performance. Then the alternative method is proposed to establish the relationship between the fitness level of the new population to f' and f_a.

II. An improved genetic-feed forward backpropagation neural network

A. Backpropagation neural network

BPNN is a multilayer feedforward network trained by error backpropagation[6-7]. For SOC prediction, the number of implicit layers is determined according to Equation (1)[8],

$$h=(m+n)^{1/2}+\sigma \tag{1}$$

Then, a framework of 2-7-1 pattern of BPNN is established. The topology can be observed in **Figure 1**.

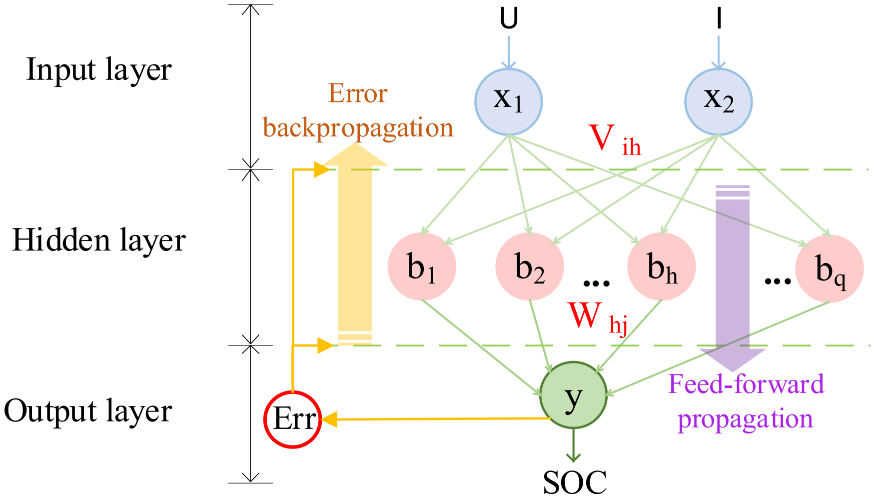


Figure 1. The topology of a three-layer BPNN

B. An improved genetic-feed forward backpropagation neural network

Introduced the elite retention method to keep 30% population with best performance, then proposed an alternative method. The flow chart of the improved GA-BPNN is shown in **Figure 2**.

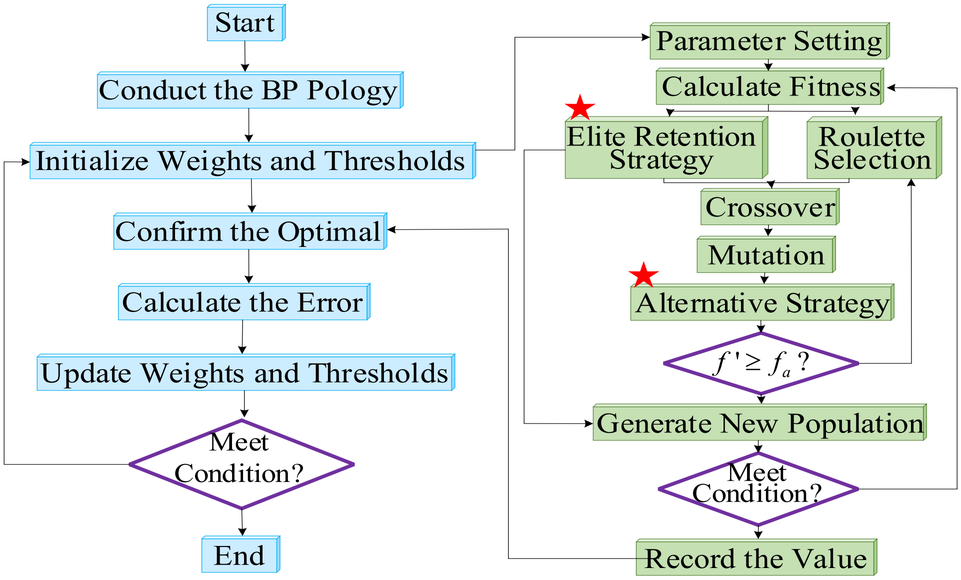


Figure 2. The flow chart of the improved GA-BPNN

An alternative strategy is introduced to solve the problem of premature maturation, which can reduce the time to find the optimal and increase the speed of evolution. The alternative operation can be achieved by f' and f_a through the following rules

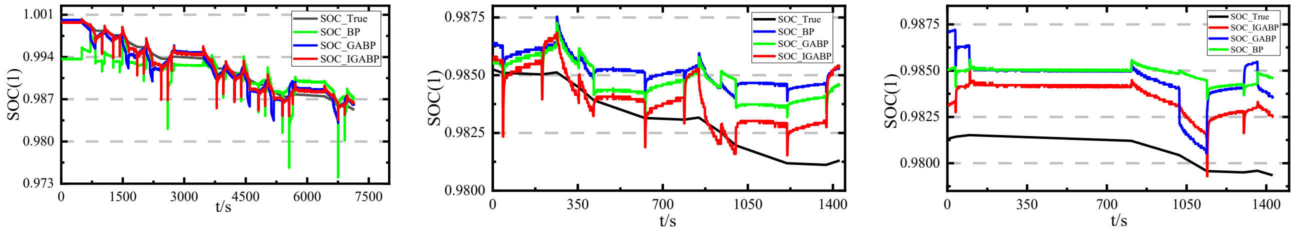
$$\begin{cases} f' \geq f_a, Roulette \\ f' < f_a, p = k\dfrac{f_a - f'}{T} \end{cases} \tag{2}$$

which can speed up convergence and to improve the learning efficiency of the network by gradually decreasing T as the number of iterations increases.

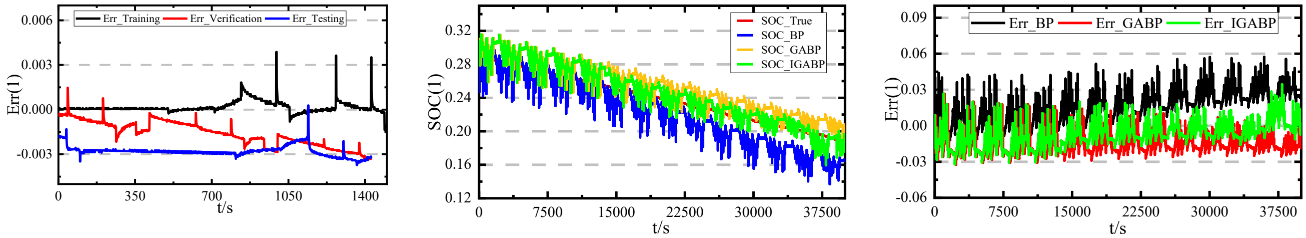
III. Experimental testing and analysis

A. Analysis of BBDST working condition

Following the pretreatment methods as proposed, the BBDST data is divided into ten groups and each group has three parts. 70% is used to train the network, 15% is set as verification and testing of each group, and the results of a certain group are shown in **Figure 3.**



(a) Training results (b)Verification results (c) Test results



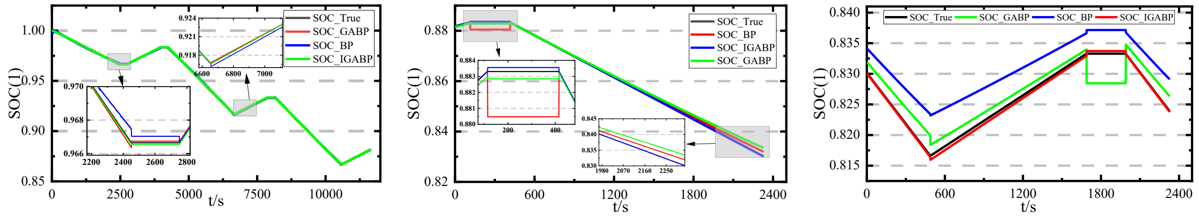
(d) Error curve (e) SOC estimation results (f) Error curves

Figure 3. Test results under BBDST

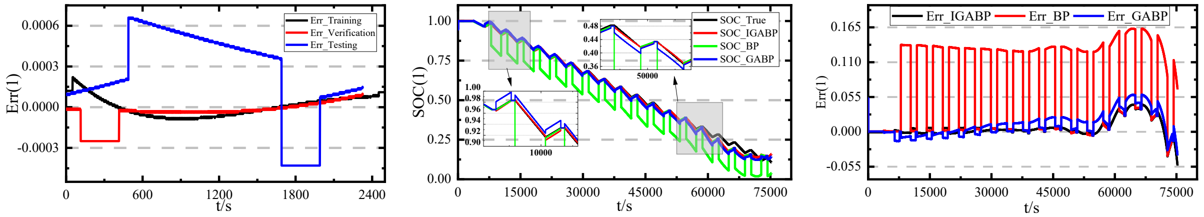
It can be observed from sub-**Figure 3** (a) that in the training process, the improved GA-BPNN has better performance with the R^2 at 0.97282 which is compared with BP at 0.58152 and traditional GA-BPNN at 0.90141.

B. Analysis of DST working condition

The curves of the three processes under the DST working condition are shown in **Figure 4**.



(a) Training result (b) Verification result (c) Testing result



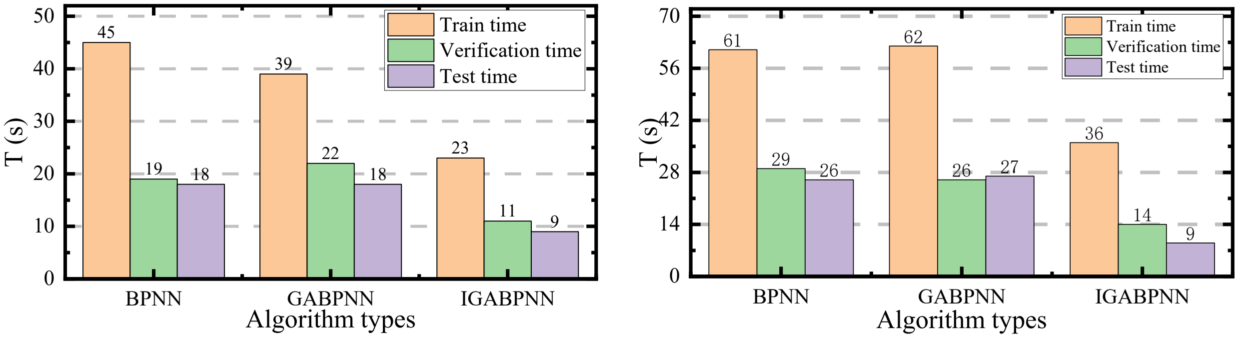
(d) Error curve (e) SOC estimation results (f) Error curves

Figure 4. Curves under DST working condition

In **Figure 4**, the R^2 of the improved GA-BPNN reached 0.98046, compared with 0.53219 of BPNN and 0.91878 of traditional GA-BPNN.

C. Result verification and comparison

It can be observed that the maximum estimation error of the improved GA-BPNN is stably controlled within 0.0812%, which is 6.523% and 1.361% higher than those of the BPNN and traditional GA-BPNN, respectively. And the time consumption under two working conditions is recorded in **Figure 5**.



(a) Time consumption under BBDST (b) Time consumption under DST

Figure 5. Time consumption of processes

In **Figure 5**, the improved GA-BPNN takes the half time in the process of training, verification, and testing, compared with BPNN, traditional GA-BPNN.

IV. Conclusion

In this research, to achieve a high- precision state of charge estimation of lithium-ion batteries, an improved genetic algorithm-three-layer backpropagation neural network is established, which set the voltage, current as the input layer, and the SOC as the output layer. To improve the ability to avoid the local optimal, the genetic algorithm is analyzed to optimize the weights and thresholds of the backpropagation. The performance of the improved genetic algorithm-backpropagation neural network is verified under complex working conditions, which is 7.92% and 6.71% higher than that of traditional GABPNN, respectively.

Acknowledgments

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