Machine Learning-Based Sensor Data Modeling Methods for Power Transformer PHM

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Published in Journal MDPI-Sensors 2018, 18, 4430

Introduction

Prognostic and System Health Management (PHM) generally provides capabilities such as fault detection, fault prediction, and component life tracking to assess product reliability. PHM technologies include sensing, anomaly detection, diagnosis, prediction and decision support for intelligent machinery maintenance and health operation. Taking advantage of advances in sensor technologies, PHM enables a pro-active fault prevention strategy through continuously monitoring the health of complex systems. A power transformer is a piece of equipment that is of great importance to the electronic system. Thus, its performance can have a great impact on the power grid. Power transformer aging is an important factor leading to grid failure, which can also cause three main fault types in transformers: electrical, mechanical, and thermal failure. Among them, mechanical failure ranks first. Therefore, it is critical to improve the accuracy of fault diagnosis of power transformers.

To develop machine learning-based models for transformer PHM, in this paper, we proposed a novel method to enhance the cuckoo search algorithm for optimizing the parameters of multi-layer back-propagation neural network for fault diagnosis of a power transformer.

Keywords: machine learning; effective cuckoo search; BP neural network; power transformer PHM; fault diagnosis

Design and Implementation

Modified Cuckoo Search (MCS) Algorithm Optimized Back-propagation (BP) Neural Network

Cuckoo Search Algorithm (CS) is a nature-inspired meta heuristic algorithm which imitates parasitic brood behavior of cuckoos. To simulate the behavior of cuckoo nesting, the CS algorithm sets three rules. The cuckoo produces an egg each time, which represents a solution to the problem, and randomly places the eggs in a nest for hatching. In addition, the number of nests is fixed and set a value Pa ∈ (0,1) to describe the probability that the nest owner finds the that the egg is a foreign egg. CS is enhanced by the Levy flight so that CS can explore global space and local space of solution and combine them with local search and global search mechanisms that make itself efficient . In addition, important parameters Pa and step-size α of CS algorithm in fine-tuning of solution vectors are used to adjust the convergence rate of the algorithm. However, the standard CS algorithm uses a constant value for these parameters by the experience. Unquestionable parameter setting and constant parameters during iterations will decrease the performance of CS algorithm.

Thus, in order to improve the ability and overcome disadvantages, a modified Cuckoo Search Algorithm (MCS) is proposed in "Modified cuckoo search algorithm and the prediction of flashover voltage of insulators.", which the main task is to implement the iterative process in which parameters Pa and α are updated via function in the appropriate range.

The fault diagnosis of a power transformer based on a MCS optimized BP neural network can be used as a comprehensive diagnosis platform, which combines the data of gas in oil with the detection system, and then obtains good results by supervised learning methods.

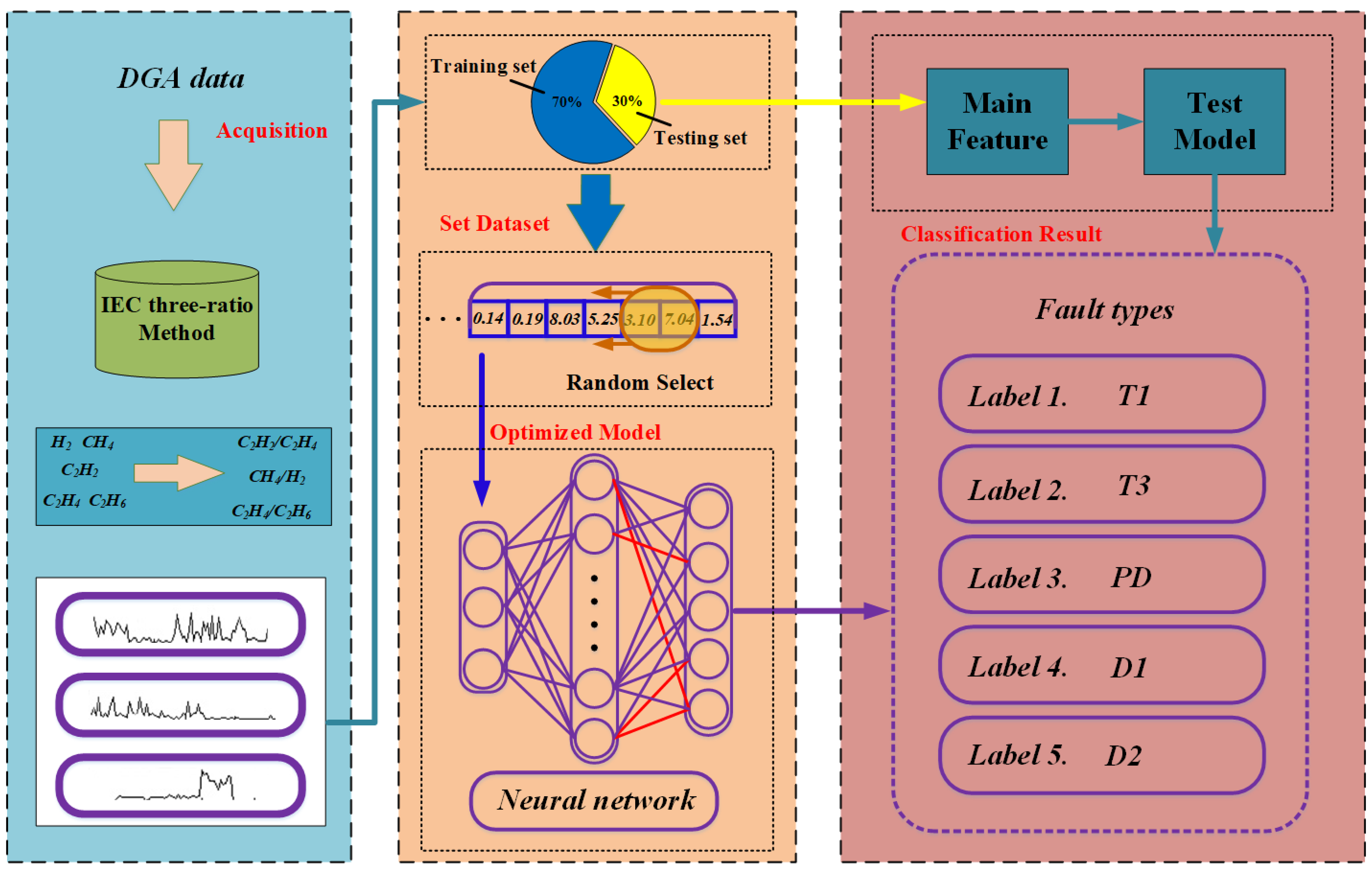

Fig. 1. Structure flow of the power transformer fault diagnosis process.

T1 represents Thermal faults T > 700°C for the oil in power transformer, T3 represents Thermal faults T > 300°C, PD is Partial Discharge, D1 is Low energy discharge, and D2 is High energy discharge. All of these representations based on the standard IEC 60599, which refers to "Interpretation of gas-in-oil analysis using new IEC publication 60599 and IEC TC 10 databases".

Results and Conclusions

The test data results in Fig.2 and Fig.3 can reflect that our model won't fall into the problem of over-fitting, and both the train sample and test samples have great classification results. It indicates that this model is helpful for fault diagnosis of power transformer because it can give a suitable decision for which the fault type of power transformer is contained.

In this paper, we propose a machine learning-based method, CS optimized BP neural network model for power transformer fault diagnosis. This algorithm can adjust the search step of solution space adaptively to find a better global optimal solution, and the fitness value of each solution is utilized to build the mutation probability to avoid local convergence. In addition, the MCS enhances the exploitation capacity and convergence rate.

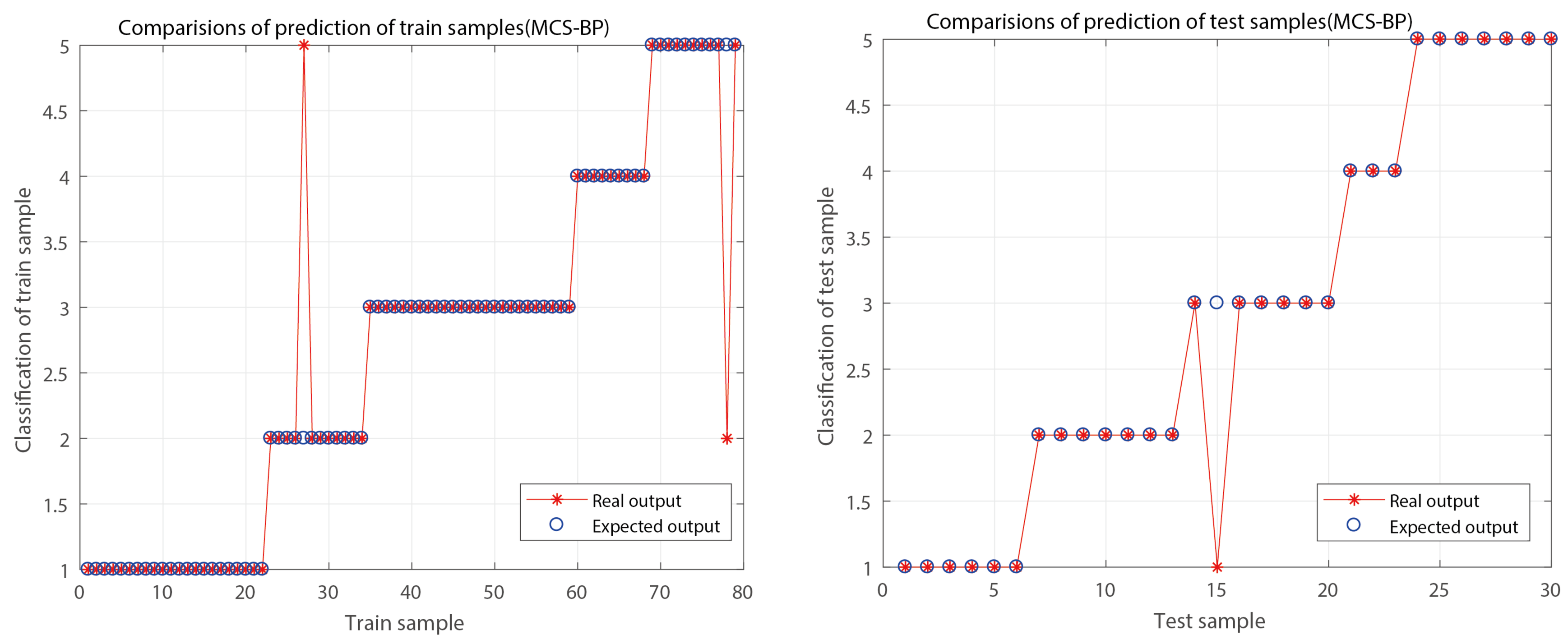

Fig. 2. The classification result of model MCS-BP for power transformer

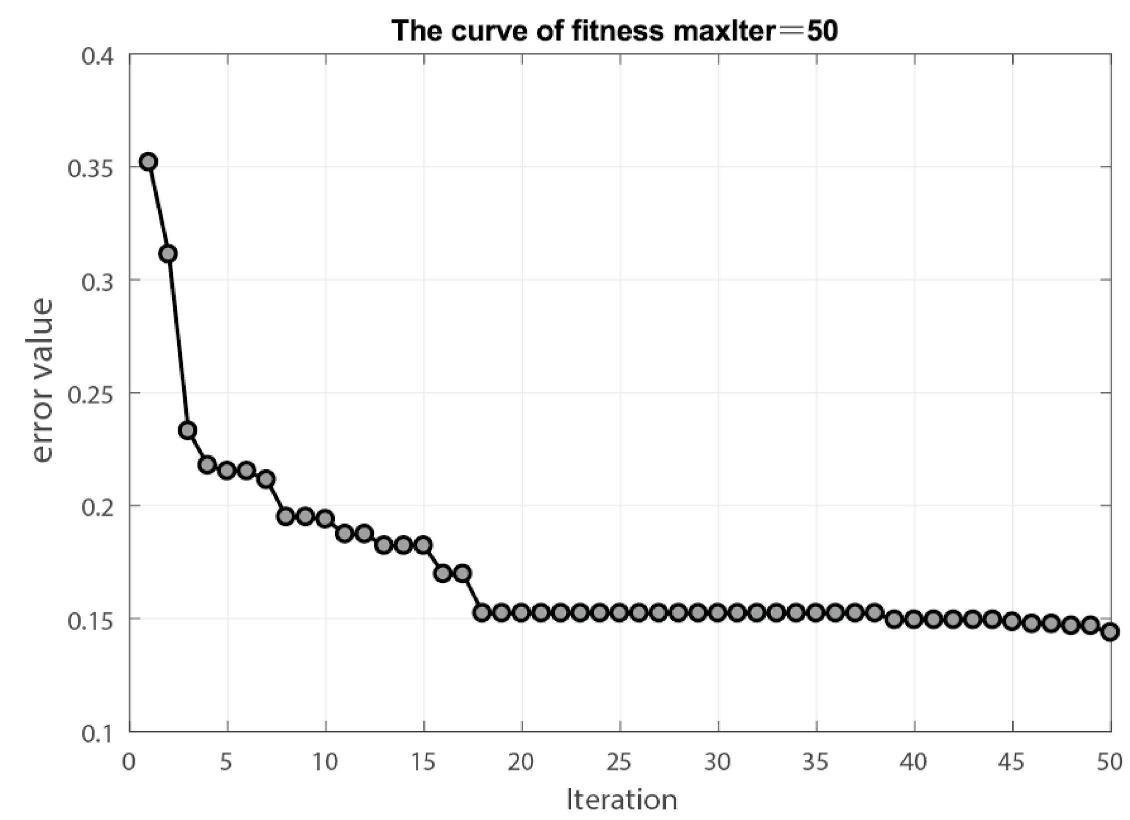

Fig. 3. The curve of fitness of MCS-BP

In addition, to clarify the optimization effect of MCS on BP during the iteration process, we consider the variation of the fitness (error) of the MCS, as shown in Fig. 3.

Acknowledgment

The authors acknowledge the department of Jiangxi power industry for providing fundamental resources for experiments and thank for Prof. Deng provides the chance to come to participate the summer school to share my ideas. This work was supported in part by the National Science Foundation of China (51765042, 61463031, 61662044, 61773051), the Jiangxi Provincial Department of Science and Technology JXYJG-2017-02.