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Research on the mainstream analog circuit fault diagnosis methods

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Abstract. Electronic products have been an indispensable part of people's daily life, in which the circuit as the basis of electronic products plays a very important role. However, when the circuit is damaged, the cause is very complicated and difficult to judge directly, so the fault diagnosis of the circuit is very important. In the past five years, this paper has studied circuit fault diagnosis methods, most of which are based on analog circuits. In recent years, the mode of building a platform based on artificial intelligence algorithms and joint software has become relatively mature. This paper summarizes and discusses the research on algorithms, artificial intelligence, and software. According to the discussion, it is found that the various researches on this model have made great progress in the past five years, and the direction of analog circuit diagnosis will have more practical opportunities in the future.

Keywords: Analog Circuit, Fault Diagnosis, Artificial Intelligence, Software Association.

1. Introduction

Circuits affect all aspects of people's lives in modern life, and when a circuit fails, the traditional method takes a lot of time to deal with it, and the usual circuit simulation software will not reveal the specific cause of the fault. At this time, intelligent fault diagnosis of analog circuits is very important. In recent years, there have been more and more methods for fault diagnosis in analog circuits. This paper will focus on summarizing and introducing several diagnostic methods.

In the past five years, the fault diagnosis methods of analog circuits have been extensively studied and explored.The purpose of this paper is to summarize these methods in order to provide more inspiration and guidance for various industries in circuit fault analysis. The main body of the paper is divided into three parts. The first part is to diagnose through algorithm optimization. In this part, this paper introduces three papers about it, which will be introduced in the main body. The second part is optimization through software associations. In this part, this paper introduces two relevant papers. The third part is optimization through artificial intelligence and deep learning. In this part, this paper will introduce one paper. By comparing the advantages and disadvantages of different methods, we can draw some conclusions and insights, which will play a positive role in promoting the accuracy and speed of intelligent circuit diagnosis in the future. These fault diagnosis methods are of great significance to various industries. In the manufacturing industry, it can help improve product quality and production efficiency and reduce losses caused by failures. In the field of energy, it can optimize the operation and maintenance of power systems, improve energy efficiency, and improve system stability. In the

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healthcare industry, it can be helpful to monitor the status of medical devices in real time and identify and resolve potential failure problems in a timely manner. In the field of transportation, it can improve the safety and reliability of vehicles and transportation facilities.

2. Algorithm optimization fault diagnosis

These three methods all use different algorithms for fault diagnosis based on SVM model. SVM, that is, support vector machine, is a two-class classification model. Its basic model is the linear classifier with the largest interval in the feature space, which distinguishes it from the perceptron most. Support vector machines also include kernel tricks, which make them essentially nonlinear classifiers. The learning strategy of support vector machine is to maximize the interval, which can be formalized as a problem of solving convex quadratic programming. The learning algorithm of support vector machine is the best algorithm for solving convex quadratic programming.

2.1. Analog circuit fault diagnosis method based on CBA-SVM

In this paper, the author introduces a bat algorithm with good global optimization based on SVM fault diagnosis. Yang, an academic at Cambridge University, proposed the bat algorithm in 2010. Many scholars consider it a new algorithm, and its service performance should be the best. In order to make global optimization performance as good as we can, this paper uses a chaotic optimization algorithm to update formulas and parameters, which will get the best fault diagnosis mode.

The fault diagnosis process based on CBA-SVM is as follows: first, collect and prehandle fault data; then, choose wavelet packet energy spectrum as fault characteristics; and finally, gain training data sets and test sets. Then, choosing the chaotic bat optimization algorithm, optimize the SVM penalty parameter C and the kernel width σ of the kernel function. After optimization parameters, recognition and accuracy rates are the largest, which is the best optimization target. The process is shown in Figure 1.

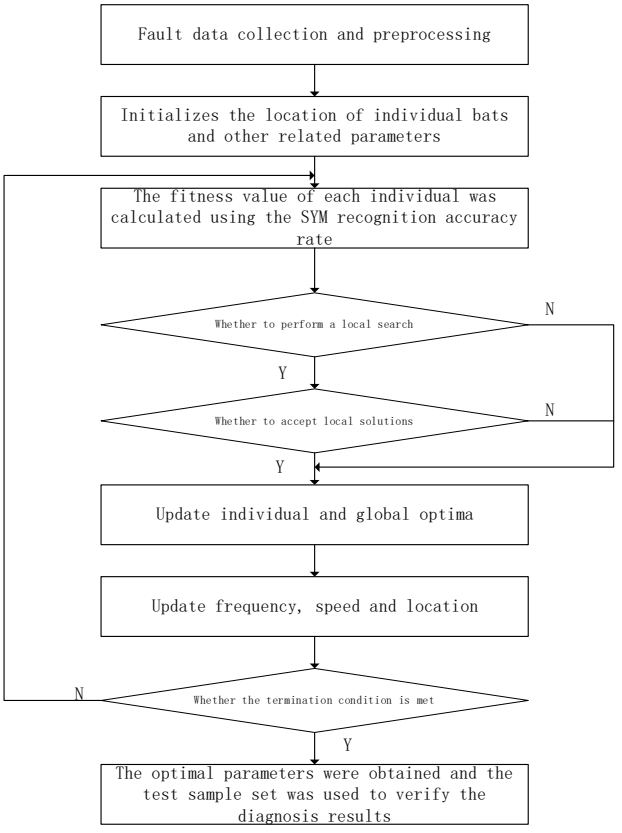

Figure 1. Optimize the SVM process based on the bat algorithm.

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In this paper, the author chooses PSPICE to simulate a circuit. Using Taking the proportional integration circuit of the self-test module of the radar seeker test system as an example. The author choose to compare with PSO and GSA to test the superiority of scheme selection. Setting the same parameter, assuming the population number is 20, the maximum number of iterations is 100, [10-1, 10 2] is the change interval of the multiplication parameter C, and [10-2, 10] is the change interval of the kernel function parameter σ [1]. The results of three algorithmic diagnosis are shown in table 1. In terms of operation speed, GSA-SVM is slower than PSO-SVM, but the former has a high diagnostic rate, and CBA-SVM has the best recognition rate.

Table 1. Comparison of fault diagnosis method.

algorithm	diagnostic rate(%)	running time(s)
GSA-SVM	96	14. 6
CBA-SVM	98. 2	10. 7
PSO-SVM	91. 1	11. 6

2.2. Analog circuit fault diagnosis based on PSO-SVM

The author of this paper uses PSO algorithm to optimize SVM model parameters. This paper also use wavelet analysis, which increases the ability of local analysis of signals compared with Fourier transform, and can deal with complex nonlinear signals that Fourier transform cannot deal with. What's more, wavelet analysis has strong anti-interference and noise removal ability. Therefore, this paper uses it to implementation feature extraction. PSO means paper swarm optimization, which is a population intelligence algorithm and was first proposed in 1995 by J. K. Enndy and R. C. Eberhart [2]. Then this algorithm is run, it first generates a population composed of several papers, and each paper in the population has its initial position and initial velocity. After that, the algorithm starts to optimize the papers in the population gradually through cooperation and competition mechanism, which is called iterative optimization process. After a certain number of iterations, the optimal solution is obtained, and the cycle ends and the result is output.

The process of PSO-SVM is similar to that of PSO, the biggest difference is that PSO-SVM uses support vector machine to iteratively update the ppaper velocity and ppaper position in the population to find the optimal ppaper.

Finally, this paper compare PSO-SVM model with random parameter SVM model. From the result, it found that different parameters affect the accuracy of fault diagnosis. The simulation circuit fault diagnosis model with optimized SVM parameters based on PSO has reasonable parameter selection and improved diagnosis accuracy compared with the SVM model with random parameters. Therefore, the PSO-SVM simulation circuit fault diagnosis model is adopted in this paper. Then, this article uses LabVIEW to build an analog circuit fault diagnosis system.

2.3. Analog circuit fault diagnosis method based on improved VMD and SVM

VMD is a common fault feature extraction method, which can decompose the original signal s (t) into components with different center frequencies. These components are defined as IMF under different bandwidth conditions. The first problem of VMD work is to construct a constrained variational equation and solve the optimal solution of the constrained variational equation. MPE algorithm is multi-scale permutation entropy algorithm. CMPE algorithm is a kind of mathematical idea which is improved by introducing a new parameter k based on MPE algorithm. The author of this paper find that SVM also has certain limitations. It is extremely dependent on good kernel function selection, and is particularly strict on the value of penalty factor c and kernel function parameter g. Moreover, when there are too many samples, SVM training time will increase exponentially, which is not conducive to real-time diagnosis of analog circuit faults. In this paper, SSA is proposed to optimize parameters c and g. SSA is a new iterative optimization algorithm proposed in 2020, with high local search capability and convergence performance, which can reduce SVM training time and effectively improve diagnosis efficiency [3]. This paper, the fault signal is decomposed based on VMD-CMPE algorithm, the fault

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feature vector is constructed, and the fault identification is completed by combining the SSA-SVM model. The construction process of the classification model is shown in Figure 2.

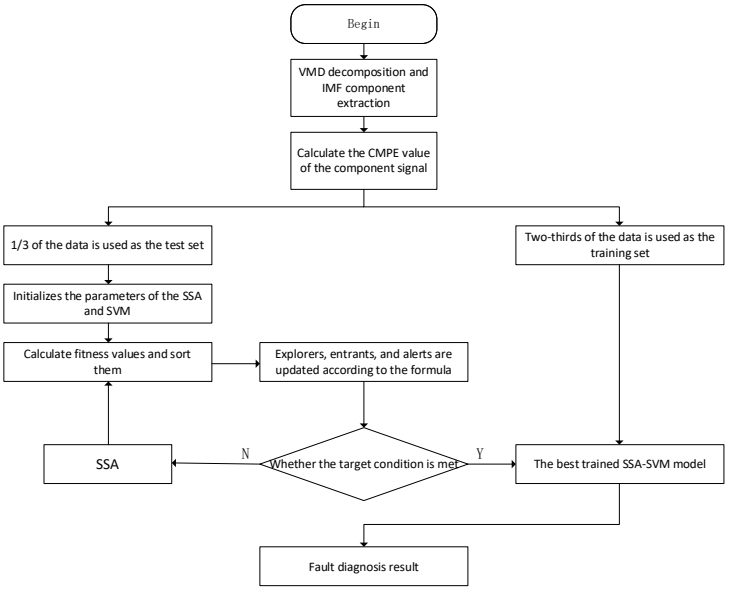

Figure 2. VMD-CMPE-SSA-SVM classification model construction process.

In order to prove the stability of SSA, the average and standard deviation of fitness values of different algorithms in the iterative process were calculated, and make Table 2

Table 2. Optimization iterative process based on different algorithms.

algorithm	mean	Std
GASVM	9. 7549e-10	1. 3007e-10
PSO-SVM	4. 6408e-12	1. 1979e-12
GWO-SVM	1. 5225e-19	1. 5564e-19
SSA-SVM	0	0

Aiming at the existing problems of analog circuit fault diagnosis, this paper presents a new algorithm of improved VMD and SVM. The experimental results after simulation show that:

(1) Combining the respective advantages of VMD and CMPE, very ideal feature information can be extracted, and the fault feature vector constructed has a good distinguishable degree.

(2) The classification network based on SSA-SVM can improve the performance of the ordinary SVM network, improve the convergence performance, and significantly accelerate the diagnosis speed. Moreover, the overall diagnosis accuracy based on the proposed algorithm reaches 99. 67%, which proves that the proposed algorithm has strong stability and real-time.

3. Fault diagnosis using artificial intelligence deep learning

Fault diagnosis using artificial intelligence deep learning is a technique that utilizes deep learning algorithms to automatically detect and diagnose faults or anomalies in various systems or processes. It involves training a deep neural network on a large dataset of normal and faulty system behavior, allowing the model to learn patterns and identify deviations from normal operation. By analyzing sensor data or other relevant inputs, the AI model can accurately classify and diagnose faults, enabling proactive maintenance and reducing downtime. This approach has shown promising results in various domains, including manufacturing, energy, healthcare, and transportation.

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3.1. Deep learning analog circuit fault diagnosis based on self-attention mechanism

Although the traditional machine learning algorithm has achieved good results in analog circuit fault detection, there are some limitations in the traditional algorithm. In this paper, a deep learning method based on audio classification is adopted to solve the problem of analog circuit fault detection [4]. That is, the output signal of an analog circuit is sampled into an audio signal; thus, the problem of analog signal recognition is transformed into an audio classification problem. Thus, we can directly make full use of the achievements of deep learning in audio classification field to improve the ability of analog circuit fault monitoring.

The audio spectrum transform network first maps the audio to the spectrum map, and then migrates the efficient data image conversion network based on the traditional natural image data set ImageNet to the spectrum classification, so as to realize the audio classification. Since the output signal of the analog circuit is a timing signal, the fault detection of the analog circuit can also be realized through audio classification after sampling into audio signals.

In this paper, firstly, the collected data set is preprocessed and divided into a training set, a verification set, and a test set by 70%, 20%, and 10%, respectively. Load the pre-trained self-attention transformation network model, input data for training and verification, and calculate the loss function. Judge whether the loss function is collected, and continue training and verification if it is not convergent; Convergence saves the model. The trained model is loaded and its performance is tested with test set. Finally, a model for detecting analog circuit faults is obtained.

In this paper, the frequency spectrum conversion technology is used to map the audio signal converted from the original data into a spectrum diagram as the input of the algorithm model. Optimization methods such as data enhancement and Dropout are adopted to effectively prevent model overfitting and improve the robustness and generalization ability of the detection algorithm. Finally, the average accuracy rate of analog circuit fault detection reaches 93.9%. The feasibility and effectiveness of the proposed ideas are fully verified. In the future, it can be further applied to large-scale analog circuit fault diagnosis.

3.2. Research on fault diagnosis of analog circuit based on BP neural network algorithm

Neural network algorithm is a cross-type frontier discipline, and has become a research point integrating artificial intelligence, cognition, graphics and nonlinear dynamics. Its research fields include connected memory, autonomous learning and machine vision [5]. The basic framework of neural network algorithm is the simplification and modeling of biological brain neurons, so the application advantages of neural network algorithm lie in parallelism, fault tolerance, associative memory efficiency and nonlinear global. Because neural network algorithm belongs to a cross-type edge discipline and integrates artificial intelligence, cognitive science, graphics and non-linear dynamics, it is advantageous to introduce analog circuit fault testing.

The BP neural network model consists of one input layer, one or more hidden layers and one output layer. The typical model architecture is diffusion network. There are multiple nodes in each layer of the network, and each node is a divine element. The data is transmitted unidirectionally from the input layer, and each hidden layer is used to reach the output layer, and finally the output of the whole network is obtained. The learning process of BP neural network can be divided into two parts: forward transfer and reverse transfer. In the BP neural network, there is no coupling relationship between neurons of the same level, and neurons only appear in the input of the lower layer neurons and have an effect on the lower layer neurons. The fault diagnosis process of the analog circuit is to first measure the fault data of the circuit waiting to be measured under various fault conditions, and use the state of the obtained data, such as the amplitude and frequency state of the analog circuit network, the voltage data and the current data of the test point, and record the correlation between the analog circuit network state and the fault characteristics. In the actual calculation process, the data of the test circuit should be obtained at any time, and its state characteristics should be extracted, and the fault types obtained in the fault dictionary should be searched.

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In this paper, the BP neural network method is used to construct a fault dictionary that can not only recognize the existing training model but also predict and recognize the information that does not appear.

4. Optimization of simulation software joint diagnosis platform

In recent years, the fault diagnosis of analog circuits has been separated from various software, through which the platform can be built so that the diagnosis method can be put into use, and the joint simulation of various software can build the platform more efficiently. Matlab is a very commonly used software, and the platform construction based on matlab has very high practical value.

4.1. Research on simulation platform of analog circuit fault diagnosis based on Matlab_GUI

This paper uses the joint simulation of PSpice and Matlab. PSpice is a circuit simulation software, which can obtain accurate simulation results [6]. Matlab is composed of the main development environment, toolbox, Simulink simulation environment and other contents, with powerful data processing functions. PSpice and Matlab co-simulation can make use of their respective advantages to complete the analog circuit fault diagnosis. In analog circuit fault diagnosis, the general steps of PSpice and Matlab co-simulation are:

1) Create an analog circuit with PSpice and get the status parameters by simulation;

2) Processing state parameters with Matlab M instruction, and finally using Shenjing network toolbox for fault diagnosis.

If the analog circuit under study has many fault states, it is necessary to repeat step 1 manually repeatedly to obtain the fault parameter set, which will consume a lot of time. If neural network is used for fault diagnosis, it may be necessary to set different neural network parameters to train many times to achieve the required precision[7]. If you use the above steps, you need to repeatedly enter the same instruction, also consume a lot of time. Therefore, it is necessary to build a joint simulation platform to realize the automation of data acquisition and fault diagnosis. This paper uses the graphical user interface (GUI) environment of Matlab, combined with SLPS, BP neural network and Simulink model to design a simulation platform for fault diagnosis, which achieves the above goals.

In this paper, a method combining the SLPS module, a modification of the network meter, and an additional switching circuit is proposed to achieve automatic acquisition of analog circuit fault parameters. In this paper, Butterworth filter circuit is used for testing and accomplish design objectives. Aiming at the deficiency of the conventional method of Matlab and PSpice joint simulation, this paper designs the simulation platform of circuit fault diagnosis by using the Matlab GUI programming environment, introduces the realization principle of the platform in detail, and uses the platform to carry out the simulation circuit fault test. The test results show that the platform has good accuracy and interactivity, and achieves the purpose of automatic test.

5. Conclusion

In this paper, algorithms, artificial intelligence, deep learning and software association are discussed in the past five years of research on analog circuit fault diagnosis. Each part introduces some articles with reference nature. In terms of algorithms, SVM-based optimization algorithms have been discussed in depth, and various methods have different efficiency, accuracy and other aspects, but have achieved quite excellent performance. And through the deep learning of artificial intelligence, its accuracy can be further improved through iterative methods, so that there is still room for progress. The combined use of various software makes the previous algorithm realized, and the platform can be built to detect other circuits, which greatly improves the practicability of circuit fault diagnosis research.

However, there are some drawbacks. On the one hand, there is a lack of standardization. Currently, analog circuit fault diagnosis still lacks unified standardization methods and processes, making it difficult to effectively compare and communicate between different manufacturers and technologies. This has impacted the further development and collaboration in the industry. On the other hand, high cost and complexity. Analog circuit fault diagnosis requires expensive equipment and complex testing environments, which presents challenges for companies and research institutions. The high cost and

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complexity limit the development of the industry and make fault diagnosis services less feasible for some small businesses and individuals.

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