Research on Ship Fault Diagnosis Based on Deep Learning

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Abstract. This paper proposes a deep learning algorithm to diagnose ship faults in order to improve the accuracy and diagnostic efficiency of ship fault diagnosis. 90% of the large number of unlabeled ship operational data samples are selected for model training, and the remaining 10% is used for model testing. We optimize model parameters and improve the accuracy of the deep learning model for fault diagnosis classification. Hidden layer functions are used to extract multi-layer data features and perform feature fusion. Gain values are used to define ship faults, primary faults, secondary faults, and tertiary faults. Finally, we use the soft-max classifier to fault output the fault and get the fault level output. The experimental results on the ship simulation fault dataset show that compared with other traditional algorithms, the accuracy of the fault diagnosis of this method is greatly improved, and the simulation result is 92.5%. Experiments show that the model based on deep learning algorithm for multi-layer feature fusion training can better meet the needs of ship fault diagnosis under complex systems.

1. Introduction

In the event of a major accident in the operation of the ship system, the ship's safe operation will have a serious impact, and improving the efficiency of fault diagnosis is the direction of ship fault diagnosis. The technology of the ship system is constantly improving, the connection between the internal structure of the equipment is complicated, and the coupling work of the ship system is getting higher and higher, making the implementation of effective fault diagnosis more difficult [1]. Ship fault diagnosis is an important part of ship system maintenance decision. Therefore, how to establish an effective ship fault diagnosis technology has become the focus of research [2].

The development of artificial intelligence is currently divided into knowledge-based rules, model-based and data processing-based fault diagnosis methods [3]. The knowledge rule-based method combines artificial intelligence technology with fault diagnosis technology, and uses fault diagnosis and reasoning through knowledge rules, but it requires a lot of knowledge and experience in related fields or expert experience, so it is difficult to achieve [4]. Data-based and model-based methods are driven by data. By analyzing the relationship between device type parameters and fault types, an appropriate machine learning model is selected for fault classification. Related research scholars have published a large number of research results in this field. Lei Yagu et al. [5] overcome the dependence of fault diagnosis on empirical knowledge, extract features from equipment time domain signals, select sensitive features and pass RBF radial basis. Function neural networks reduce the network structure model. Zhou Hongming et al. [6] combined the extreme learning autoencoder with deep learning to establish a deep limit learning model. Zhao Zhihong et al [7] first used wavelet packet transform and Hilbert-Huang
transform to extract fault features, and then used SVM method to classify fault diagnosis types. By analyzing the traditional fault diagnosis classification methods such as SVM, artificial neural network and extreme learning machine ELM, the SVM algorithm can solve the complementary problem of the fault diagnosis classification algorithm and the direct training prediction problem, but the SVM algorithm requires a large number of label data samples. And it is more difficult to deal with the problem of data imbalance [8]. The difference between the observed and actual values of the artificial neural network model is compared with the decision function established in advance to determine whether the equipment fault has occurred. However, the model training process is more difficult, which makes the method have certain limitations. The ELM method is fast, but its sum function is a specified function, and the adaptability of the kernel function in processing different data is not considered, which makes the stability of the method poor. The above methods are traditional machine learning methods, the learning ability has limitations, and the accuracy of fault diagnosis is difficult to further improve [9]. In view of the above shortcomings, a deep learning method is proposed to complete the training model process from a large number of unlabeled data samples, optimize the model parameters and improve the accuracy of the deep learning model for fault diagnosis classification.

In recent years, the deep learning research boom has been rising. The deep learning algorithm is a multi-hidden layer network model structure, which can effectively analyze and extract large amounts of data, and is widely used [10]. Deep learning is mature and has significant effects in the fields of computer vision, speech recognition, image recognition and natural language processing, but deep learning applications are still in their infancy in the field of fault diagnosis. Sun et al. [11] combined the automatic encoder with the deep learning algorithm to propose a deep neural network algorithm implemented by a fine-numbered auto-encoder with denoising coding. Jia et al [12] proposed an intelligent diagnosis method based on deep learning algorithm, which overcomes the defects of traditional methods on expert experience and professional knowledge, and verifies through data sets to achieve better classification results. Lu et al. [13] used the deep learning algorithm to calculate and analyze the frequency domain data of the bearing dataset, and visualized the results to obtain better classification accuracy.

Combined with the above-mentioned application of traditional fault diagnosis technology and deep learning algorithm in the field of fault diagnosis, there are still some problems, such as the increase of data dimension and the increase of network layer. This paper proposes a ship fault diagnosis based on deep learning algorithm. The multi-layer data features are extracted by deep learning; the extracted multi-layer feature vectors are feature-fused; the soft-max classifier is used to classify and output the fault results.

2. Data acquisition and data preprocessing

2.1. Data acquisition

Due to the complexity of the actual working conditions of the ship, it is difficult to collect a large number of actual fault data due to the influence of many external environmental factors. There is no authoritative data set available in the industry. This article was completed on the lab platform. The platform includes a current sensor, a voltage sensor, a rotational speed sensor, and a tension and pressure sensor. The sensor includes four states: normal, complete failure, constant gain, and constant deviation. Faults are classified into: primary fault, secondary fault, and tertiary fault. Definition: When the gain value interval is $\pm (10\% \sim 20\%)$, it is a first-level fault; when the gain is $\pm (20\% \sim 40\%)$, it is a secondary fault; when the gain value interval is $\pm (40\% \text{ or more})$ Three-level failure. The sampling frequency is $40ks/s$, the number of samples per cycle is 4000, the normal state data is collected for $20s$, and the fault state data is collected for $20s$.

2.2. Data preprocessing

The experiment collected 61 cycles for data collection. The data set had 50020 sets of data, 90% of which were used as training sets and 10% as test sets. Because each set of data contains data from four
different sensors, the data needs to be separately Z-Score standardized to ensure the comparability between the data, defined as:

$$z = \frac{x - \mu}{\sigma}$$  \hspace{1cm} (1)

$x$ is the observed value, $\mu$ is the population mean, and $\sigma$ is the population standard deviation.

3. Modeling of ship fault diagnosis based on deep learning

The ship fault diagnosis model based on deep learning is divided into four steps: The Inception-v3 model is used to extract the feature vectors in the data set at the front end, and the feature vectors in the last two layers of the pooling layer are used for feature fusion. Vector, used as input to the Softmax classifier, to classify fault levels. The ship fault diagnosis model based on deep learning is shown in Figure 1.

![Ship Fault Diagnosis Model Based on Deep Learning](image)

Fig.1 Ship Fault Diagnosis Model Based on Deep Learning

In this paper, $R^2$ is used to judge the model fitting degree. The value of the model is used as the model score. The better the model prediction effect is, the closer the $R^2$ value is to 1, the worse the model prediction effect is, and the closer $R^2$ is to 0. The definition of $R^2$ is as follows:
\[ R^2 = 1 - \frac{\sum(y_i - f_i)^2}{\sum(y_i - \bar{y})^2} \]  

(2)

\( y \) is the actual value, \( f \) is the predicted value, and \( \bar{y} \) is the actual value of the training sample average. \( R^2 \) uses the mean as the error reference to calculate whether the prediction error is greater or less than the mean reference error. The algorithm flow is shown in Figure 2.

4. Experimental results and analysis
In order to evaluate the fault diagnosis performance of ship fault diagnosis model based on deep learning, it is compared with extreme learning machine and support vector machine algorithm. The detection accuracy and detection time of ship fault diagnosis were compared and analyzed. The accuracy comparison analysis is shown in Figure 3.
Fig. 3 Comparison of Fault Diagnosis Accuracy

As can be seen in Figure 3, compared with other intelligent algorithms, the accuracy of the fault diagnosis of the deep learning algorithm is above 92%, which is much better than the traditional algorithm. The detection time is shown in Figure 4.

5. Conclusion

With the continuous development of intelligent shipbuilding, more and more sensor data has been added to the fault diagnosis. The huge data set and the complex ship operating environment have put forward higher requirements for fault diagnosis. In this paper, a ship fault diagnosis model based on deep learning is proposed. Feature fusion is used to feature the last three layers of the hidden layer. The data set is collected on the experimental bench and the effect of the model is verified. The model parameters are continuously optimized to make it more suitable for ships troubleshooting. The average training precision of the model is 95.67%, and the average test accuracy is 92.52%, which is better than the
The experimental methods and experimental procedures proposed in this paper can be applied to ship fault diagnosis to achieve better human-computer interaction, high diagnostic efficiency and accuracy.

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