

SVM and wavelet analysis method for hydraulic pump fault of rock drilling

LIU Jian-hua, MA Wen-bin

Mechanical Engineering, Changshu institute of technology, Changshu china

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Abstract. In order to looking for the fault of rock drilling hydraulic pump, the data of pressure and flow can be collected, from which wavelet analysis was used to find characters of the fault. So a new rock drilling pump fault diagnostic model by SVM was based on the energy value of the data deal with wavelet analysis. The results of regression show that the accuracy rate of SVM2 was higher than SVM1, and different core functions can get different regression accuracy from which RBF core function was better than others.

1 Introduction

Rocking drill machine is used to tunnel drilling and bridge construction and mine operation. The most rocking drill adopt hydraulic methods to finish the drilling mission. So how to diagnose the hydraulic pump fault correctly is very important.

Traditional diagnose process is depend on the maintenance engineer, from which the incorrect results can be get easily. So how to solve the problem by artificial intelligence become the goal of many scientists. Wei Bin[1] established a diagnose model for grab by secure clustering algorithm; Jiang Wanlu[2] form a diagnose model by prove theory and multiple data fusion; Li Guo pin[3] established a diagnose model for grab by BP neural network;

The rate of hydraulic fluid and the pressure of cylinder are the main characters of the process for diagnosing hydraulic pump. Because the signals of pressure and the rate of hydraulic fluid are complex from which much noise accompanied. So this article try to adopt wavelet analysis method to explain the signals according hydraulic pump fault of rock drilling. By the energy values of wavelet layers, the diagnose model for hydraulic pump of rock drilling is established based on support vector machine(SVM) and binary tree algorithm; [2,4,5]

2. Diagnose Model

2.1. wavelet analysis

Wavelet analysis is a kind of effective signal analysis method, from which useful information can be shown by different layers according to frequency of signal.

For rigid situation of rock drilling, the signal of hydraulic pump with all kind of noise, wavelet analysis is better to deal with it. So, based on the energy values of wavelet layers, the diagnose model for hydraulic pump of rock drilling is established on support vector machine(SVM) and binary tree algorithm;

2.2 SVM algorithm

SVM is a new technology of data mining, and a new tool for machine learning using optimization method to solve the problem, which is the effective way to overcome "dimension disaster" and "learning" Deng difficult. The basic principle of SVM is through the definition of the inner product function properly, the training data set of the mapping from the input space to a high nonlinear feature space (Hilbert space), the sample can be classified in the linear space. And then SVM find the optimal linear classification the new space. [3,4,6,7,8]

SVM The kernel function:

The linear kernel function: $K(x, x_i) = x \cdot x_i$

Polynomial kernel function: $K(x, x_i) = (\gamma(x \cdot x_i) + d)^p$

rbf kernel function: $K(x, x_i) = \exp(-\gamma \|x - x_i\|^2)$

Sigmoid kernel function: $K(x, x_i) = \tanh(s(x, x_i) + q)$

2.3. Binary tree SVM algorithm

It is effective for SVM to solve the small sample learning and nonlinear problem of machine learning on better optimize algorithm. The principle of which is introducing appropriate inner kernel function and the simple data is projected to multi-dimension space, which is linear to classify the multi-dimension simple, and the optimizational result can be get.

By binary tree multi-classification ability, the multi-classification model based on SVM and binary tree algorithm is established, which is shown by Fig.1.

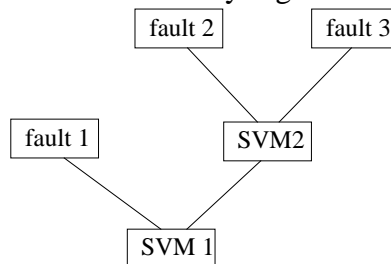


Figure.1 binary tree and SVM algorithm structure

To classify the given simple into k kinds, setting learning simple as following[7]:

$$\begin{aligned} & \{(x_1, y_1), (x_2, y_2), \dots, (x_l, y_l)\}, i, j = 1, 2, \dots, l, \\ & x_i \in R^n, y_i \in \{1, 2, \dots, k\} \end{aligned} \quad (1)$$

For the four factors simple to binary tree (F, P, SVM, SC), the following equation can be get.

$$\begin{aligned} F &= \{f_1, f_2, \dots, f_i, \dots, f_k\} \\ P &= \{p_1, p_2, \dots, p_i, \dots, p_k\} \\ SVM &= \{SVM_{p_1}, SVM_{p_2}, \dots, SVM_{p_i}, \dots, SVM_{p_k}\} \\ SC &= \{Sc_1, Sc_2, \dots, Sc_i, \dots, Sc_k\} \end{aligned} \quad (2)$$

F is the final point, which is due to k ; P is the diagnosing order: p_1, \dots, p_k . SVM are the classification models for each binary tree branch; Sc is the simple data packet. In fact the classification model is the optimum design as following:

$$\min_{\omega_i, b_i, \xi_i} \left(\frac{1}{2} \omega_i^T \omega_i + C \sum_{j=1}^l \xi_i^j \right) \quad (3)$$

$$\omega_i^T H(x_j) + b_i \begin{cases} > 1 - \xi_i^j, y_i = i \\ \leq -1 + \xi_i^j, y_i \neq i \end{cases} \quad (4)$$

Which $\xi_i^j \geq 0, j = 1, 2, \dots, l$; is $H(x_j)$ (training data that project multi-dimension space); b_i is the threshold value of classification; ω_i is the factors of classification; C is the penalty factor. The simple data of diagnosing fault of pump would be decomposed by wavelet analysis method, from which the characters of energy value of each layer would be extracted. So these character values serve as input training data in the situation of giving fault as output training data. [9, 10, 11]

3 Experiment Research

It is aimed at the faults for hydraulic pump of rock drilling such as pump's loose slipper fault,hydraulic cylinder wear fault and port plate wear fault,which the diagnosing model based on SVM and binary tree algorithm to measure the model classification ability.[12,13,14]

In the course of experiment, PCI6114 data acquisition card is used to get the pressure and the rate of flow value,for which the characters employ each layer energy value by wavelet analysis method.System structure as Figure 3

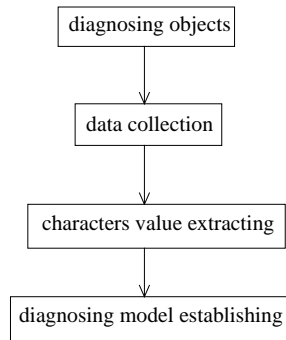


Figure 2 diagnosing model structure

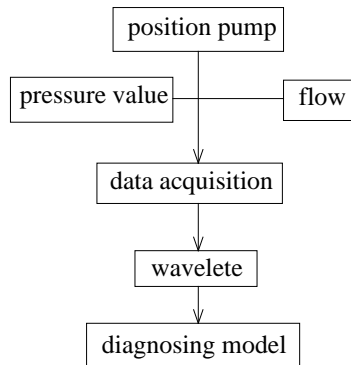


Figure 3 system structure

Part characters value of pump's loose slipper as Table 1:

press ure	d1	d2	d3	d4	d5	d6
1	0.029506	0.043815	0.27633	0.87963	1.4119	1.9723
2	0.051803	0.078831	0.39607	1.3749	3.8692	7.0552
3	0.042566	0.09669	0.48493	1.3712	1.9048	2.2763
4	0.054057	0.070846	0.36171	1.4933	4.0381	7.6359

Table 1 part characters value of pump's loose slipper

pressu re	d1	d2	d3	d4	d5	d6
1	0.01937	0.06371	0.6685	0.8863	1.2541	1.8635
	4	8	2	5	2	4
2	0.06125	0.08796	0.5365	1.4796	3.7725	7.0403
	4	5	8	5	4	5
3	0.04693	0.09687	0.5896	1.2957	1.9405	2.7786
	2	8	3	1	3	5
4	0.06390	0.08056	0.4196	1.8652	5.0685	6.3785
	2	9	3	1	2	2

Table 2 part characters value of hydraulic cylinder wear

pres sure	d1	d2	d3	d4	d5	d6
1	0.03207	0.05831	0.0636	0.8263	1.2435	1.7632
	4	8	2	5	2	4
2	0.04365	0.06216	0.7247	1.5234	1.7345	7.1523
	4	5	8	5	4	5
3	0.04533	0.08943	0.9432	1.2376	1.9239	2.7786
	2	8	3	1	3	5
4	0.07842	0.13421	0.6341	1.4731	2.0132	6.3785
	2	9	3	1	2	2

Table 3 part characters value of port plate wear

The input vectors are constructed by each layer energy value from wavelet analyze for pressure data and rate of flow data. The output vectors are built by given faults. Many times tests shown that in the condition of appropriate parameters for each kernel function, RBF owns best accuracy. Table 4 shown the different test results.

classification	linear	polymerization	RB	Sigmoid
n	r	on	F	
SVM1	85%	85%	90%	90%
SVM2	85%	85%	95%	95%

Table 4 different test results.

For SVM:1 linear: $C = 100$; polymerization $C = 10, g = 10, d = 4, p = 0.1$; RBF $C = 1, r = 1$; Sigmoid $C = 10, s = 10, q = 10$;

For SVM1 linear: $C = 100$; polymerization $C = 10, g = 10, d = 2, p = 0.1$; RBF $C = 1, r = 1$; Sigmoid $C = 10, s = 1, q = 1$;

4 Conclusion

Wavelet analyze can get effective information from experiment data, and diagnosing model base on SVM and binary tree algorithm owns the ability to judge the fault of Rocking drill pump.

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